



Defence plans and restoration: various areas for improvement identified by the project

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Defence plans and restoration

Various areas for improvement identified by the project

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Regina Llopis, Vicens Gaitán, and Milenko Halat, AIA

Luis María Zamarreño, Gridquant

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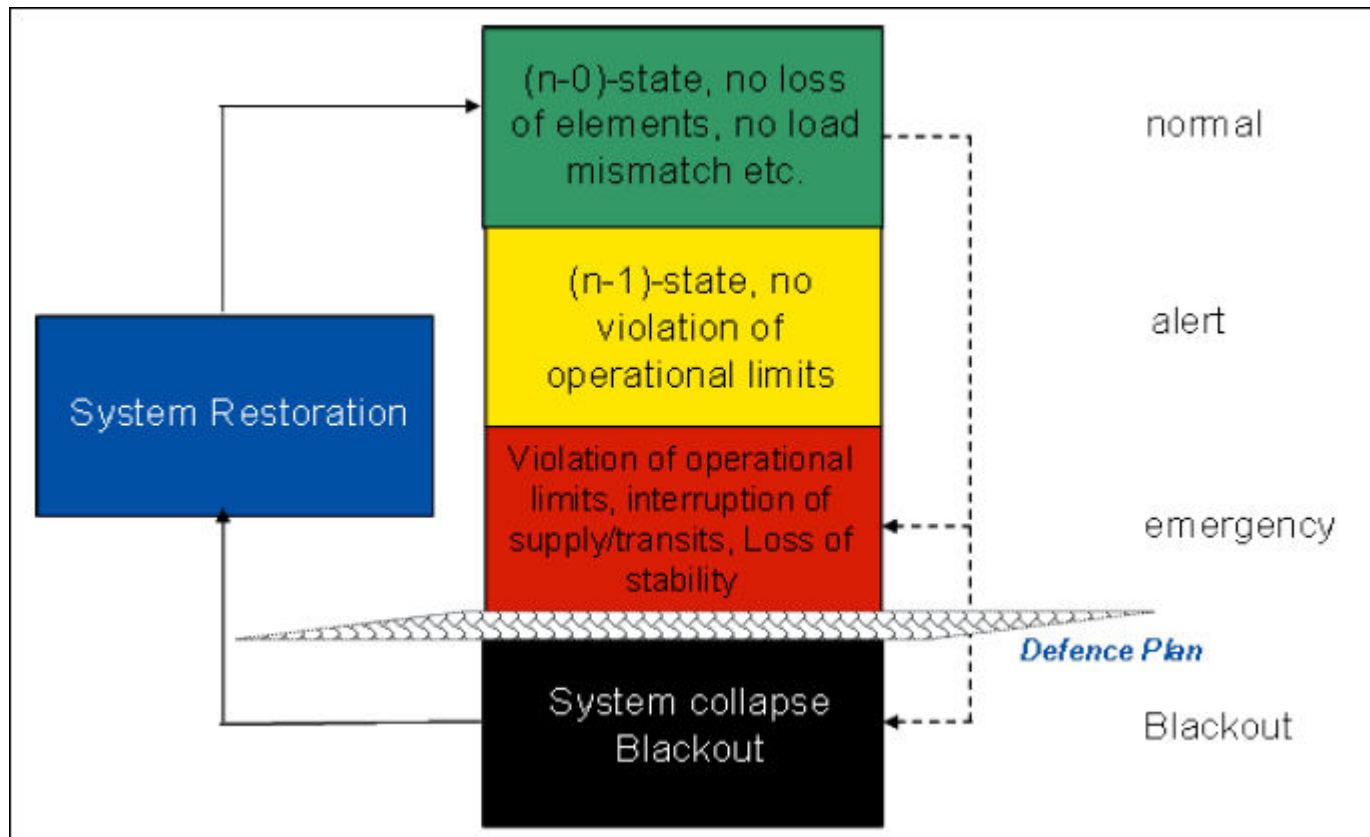
Emil Hillberg and Jukka Turunen, Statnett

Luigi Vanfretti and Rujiroj Leelaruji, KTH

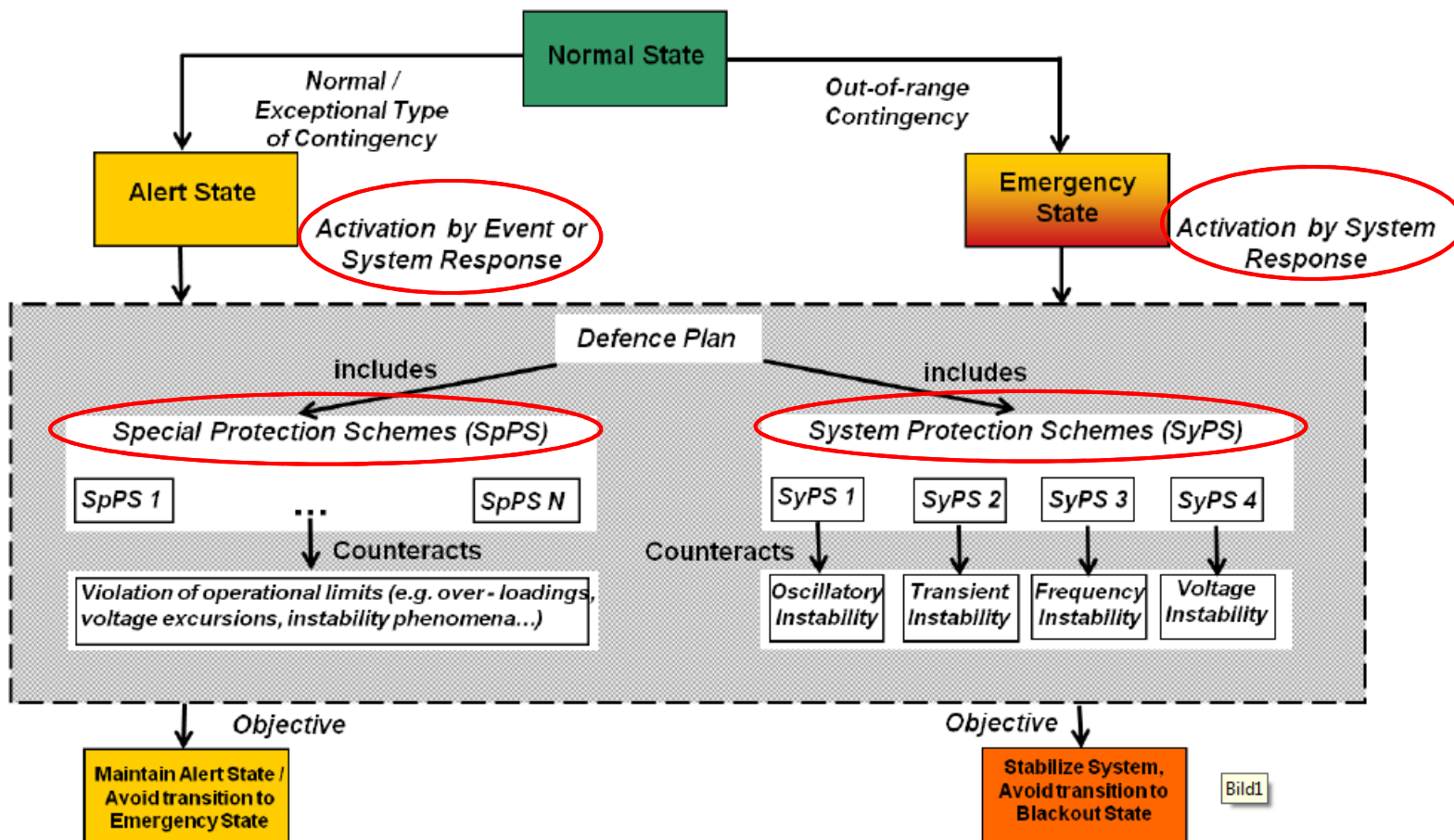
Vincenzo Trovato and Rodrigo Andres Moreno Vieyra, Imperial Collage

Luis Seca , Carlos Moreira, and André Madureira , INESC Porto

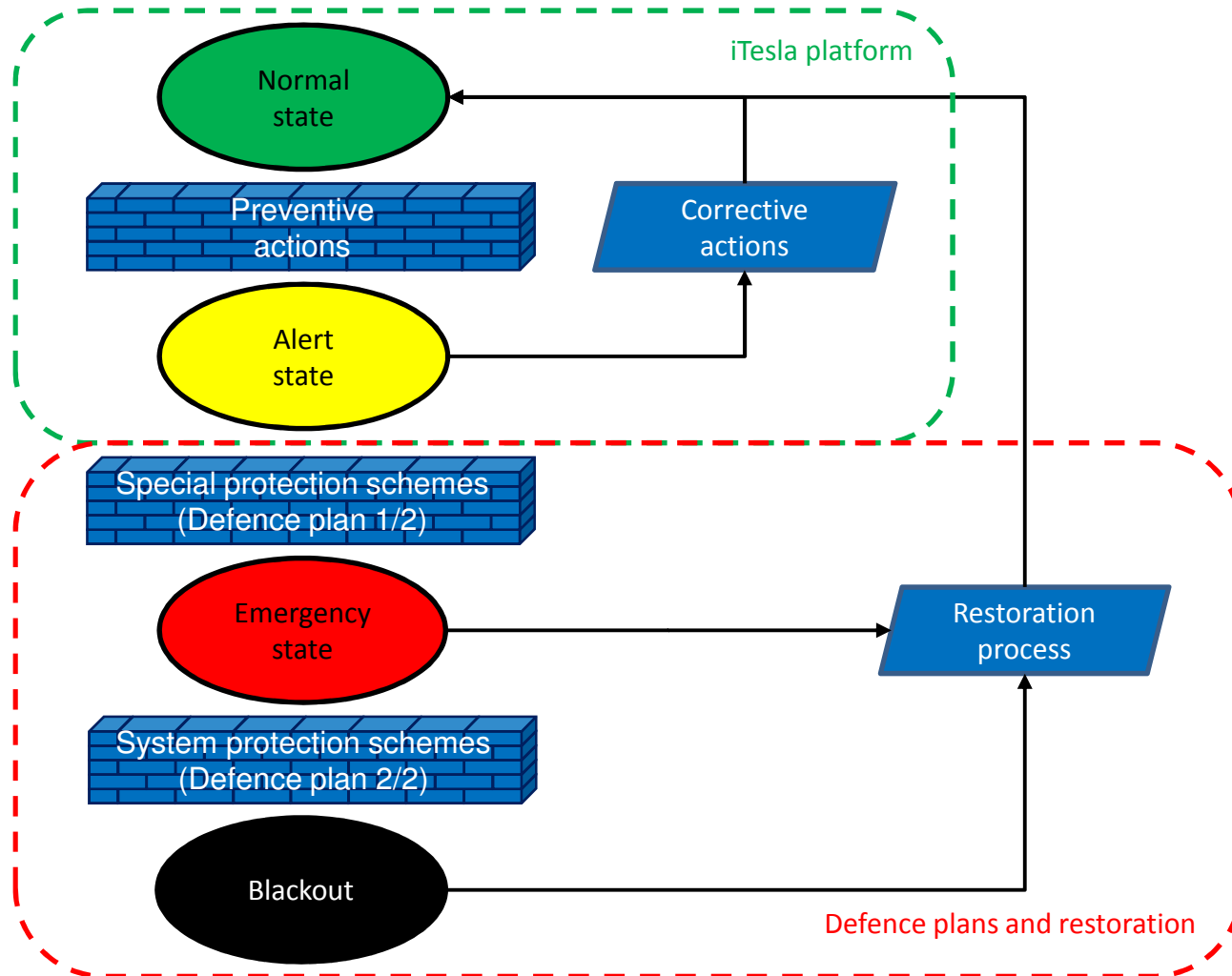
CIGRE Task Force C2.02.24 definition (2007)



ENTSO-E Special Protection Schemes (2012)

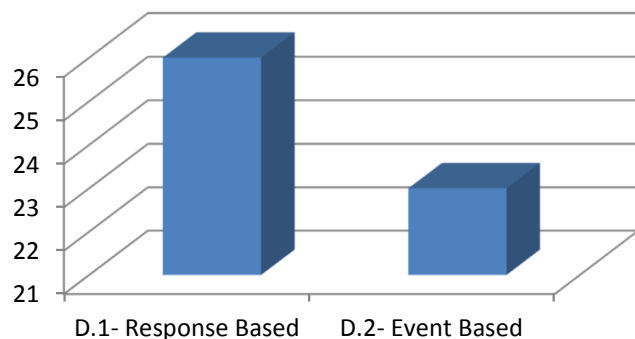


Extended definitions

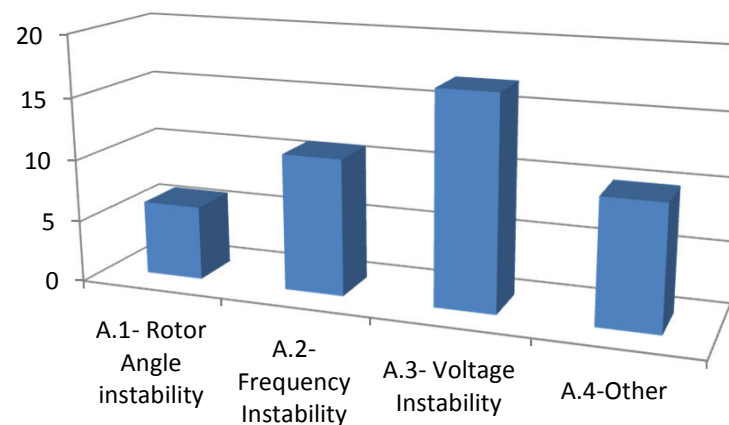


- Defense plans
 - Weak points in existing plans (AIA / KUL)
 - Role of renewable generation plants (DTU)
 - Pan-European coordination (KUL)
 - Use of PMUs (Statnett / KTH, Tractebel)
 - Use of distributed energy resources (Imperial / KUL / DTU)
- Restoration
 - Coordinated restoration (AIA / Tractebel)
 - Use of renewable generation plants (INESC)

| TSO | Country | Survey | Visit |
|---------------|----------|-------------------------------------|-------------------------------------|
| ELIA | Belgium | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| IPTO | Greece | <input checked="" type="checkbox"/> | |
| National Grid | UK | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Statnett | Norway | <input checked="" type="checkbox"/> | |
| REN | Portugal | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| RTE | France | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |



Most SPS triggering are response-based.



Voltage Stability is the main concern, but there is a considerable number of “other” instabilities

Wind power in defence plans and restoration

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4 November case

- Event:
 - Split into 3 areas
 - North-East with surplus generation (incl wind) causing overfrequency

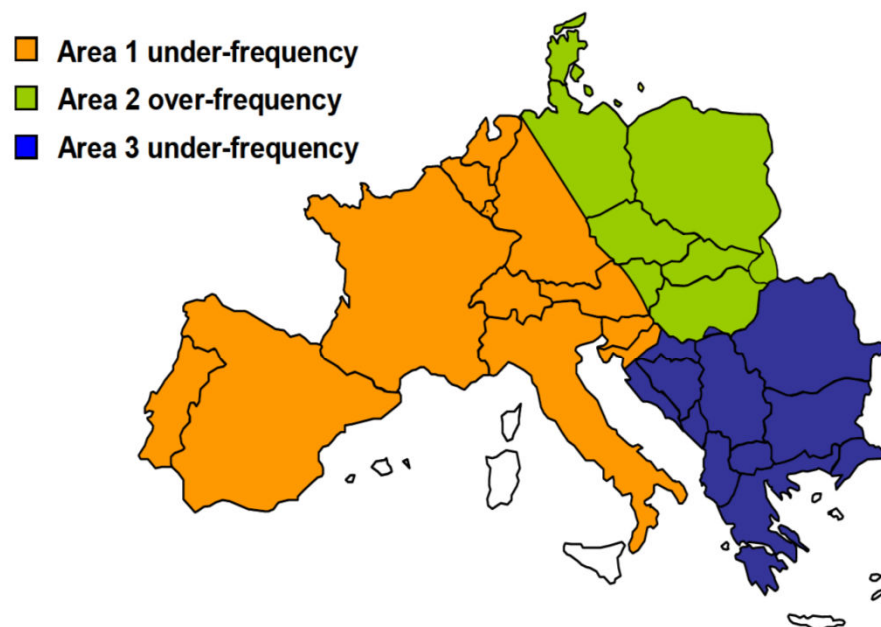


Figure 4: Schematic map of UCTE area split into three areas

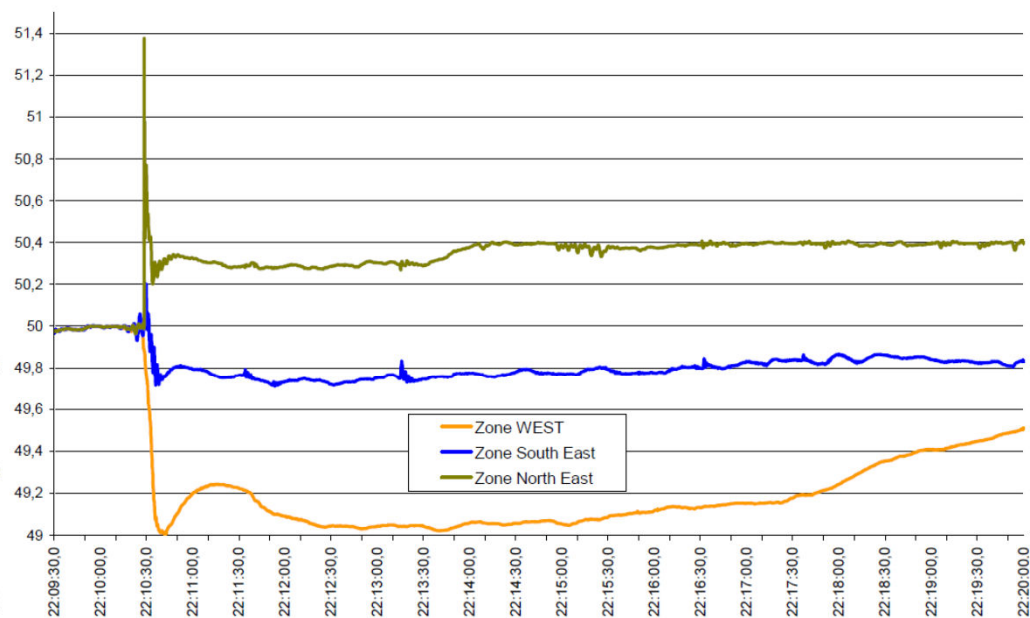


Figure 6: Frequency recordings after the split

*Final Report "System Disturbance on 4 November 2006," UCTE

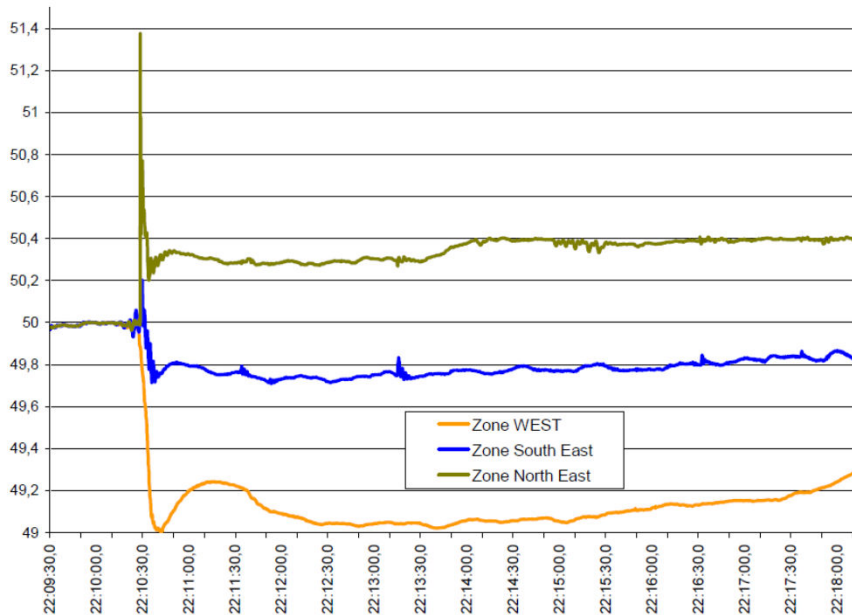
Emergency frequency control Validation case

- Starting point: Synthetic model of Europe – from Pegase
- Snapshot before events:

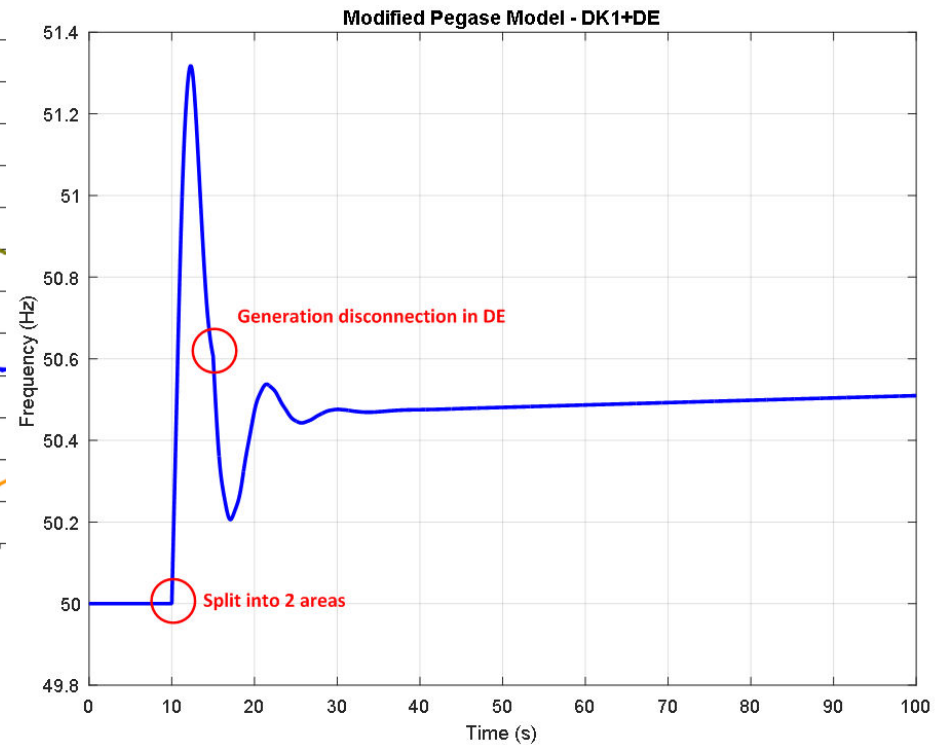
| | Germany | Denmark |
|------------------------------|---------|---------|
| Conventional generation (GW) | 45.5 | 2.0 |
| Wind generation (GW) | 8.4 | 1.0 |
| Load (GW) | 41.2 | 3.5 |
| Losses (GW) | 2.7 | 0.1 |
| Imbalance (GW) | 10.0 | -0.6 |

Synthetic case – base simulation

- Events:
 - Split into 2 areas (Germany+DK1 surplus generation 9.4 GW) at 10sec.
 - Generator disconnection (3.3 GW) in Germany at 15 sec.

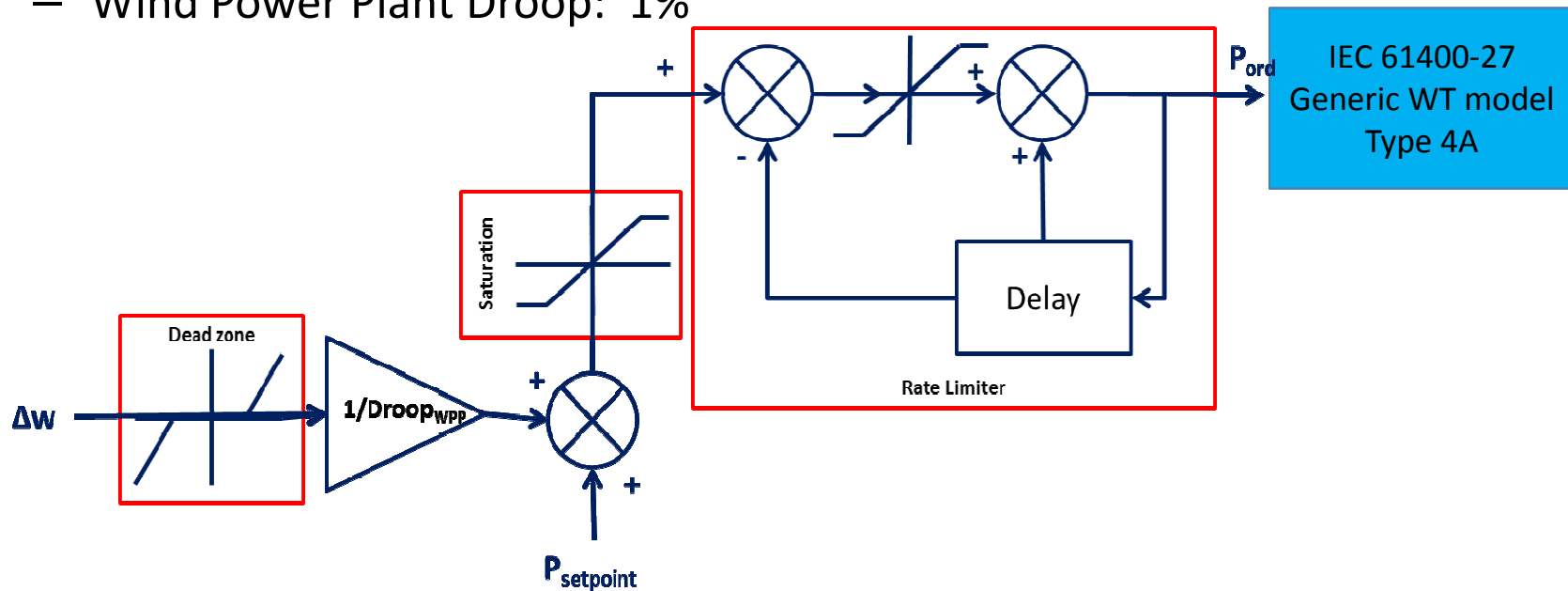


*ENTSO-E Final Report "System Disturbance on 4 November 2006,"

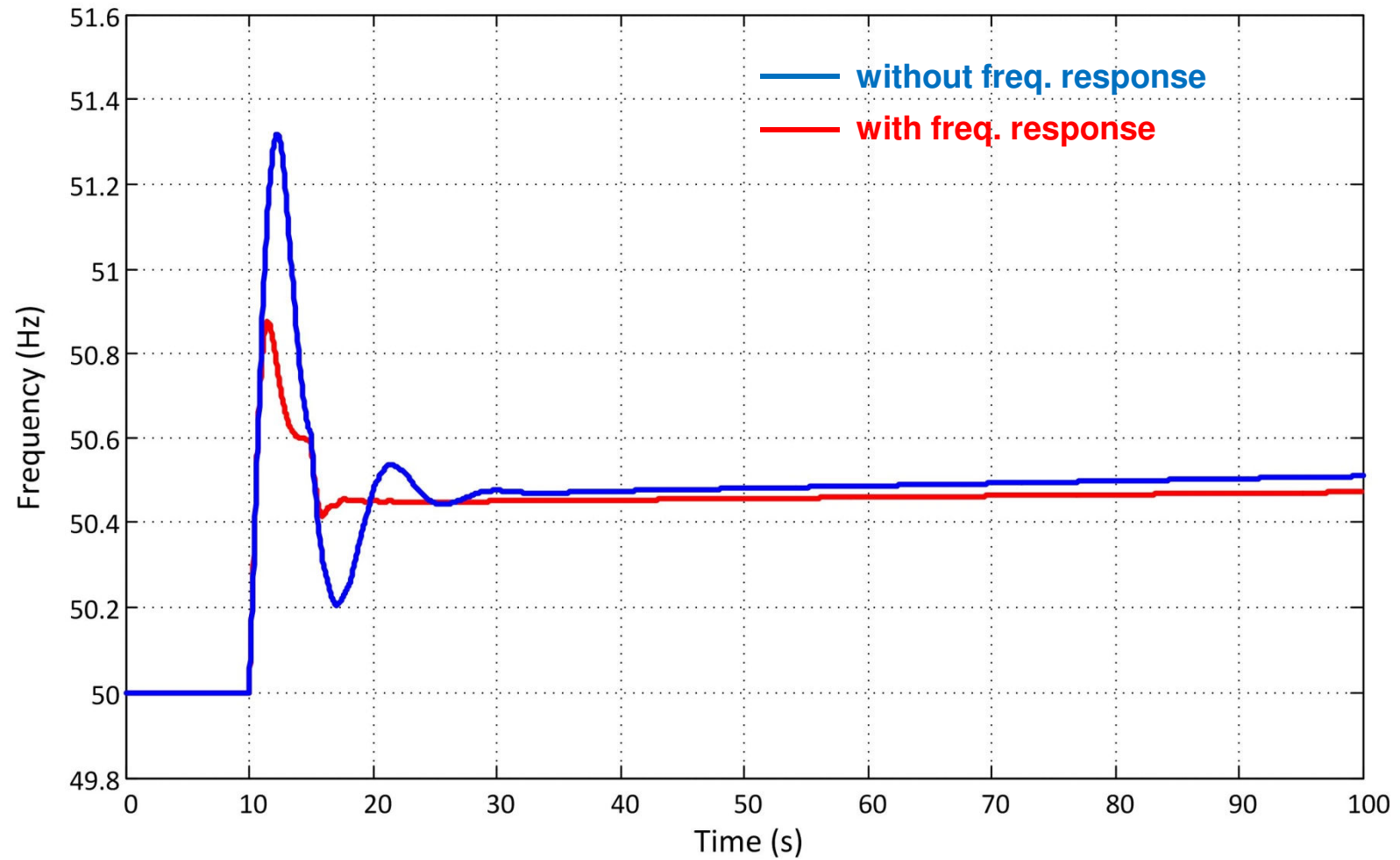


Wind power emergency control

- Model parameters ("optimized" using simplified Matlab model with 20% wind power penetration):
 - Ramp Rate Capability: 1p.u./s
 - Activation frequency: 50.4 Hz
 - Wind Power Plant Droop: 1%

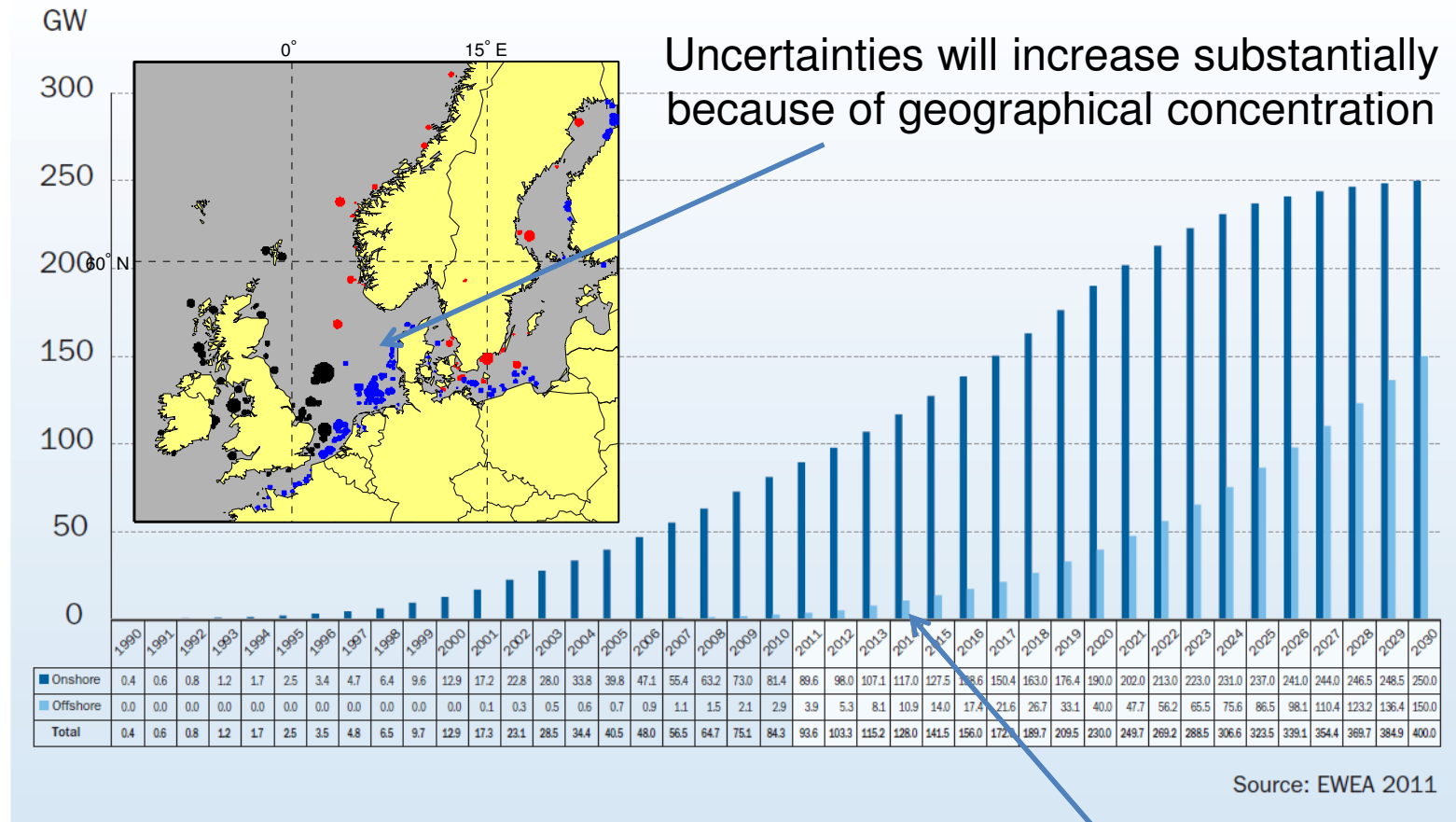


Effect of wind power emergency control



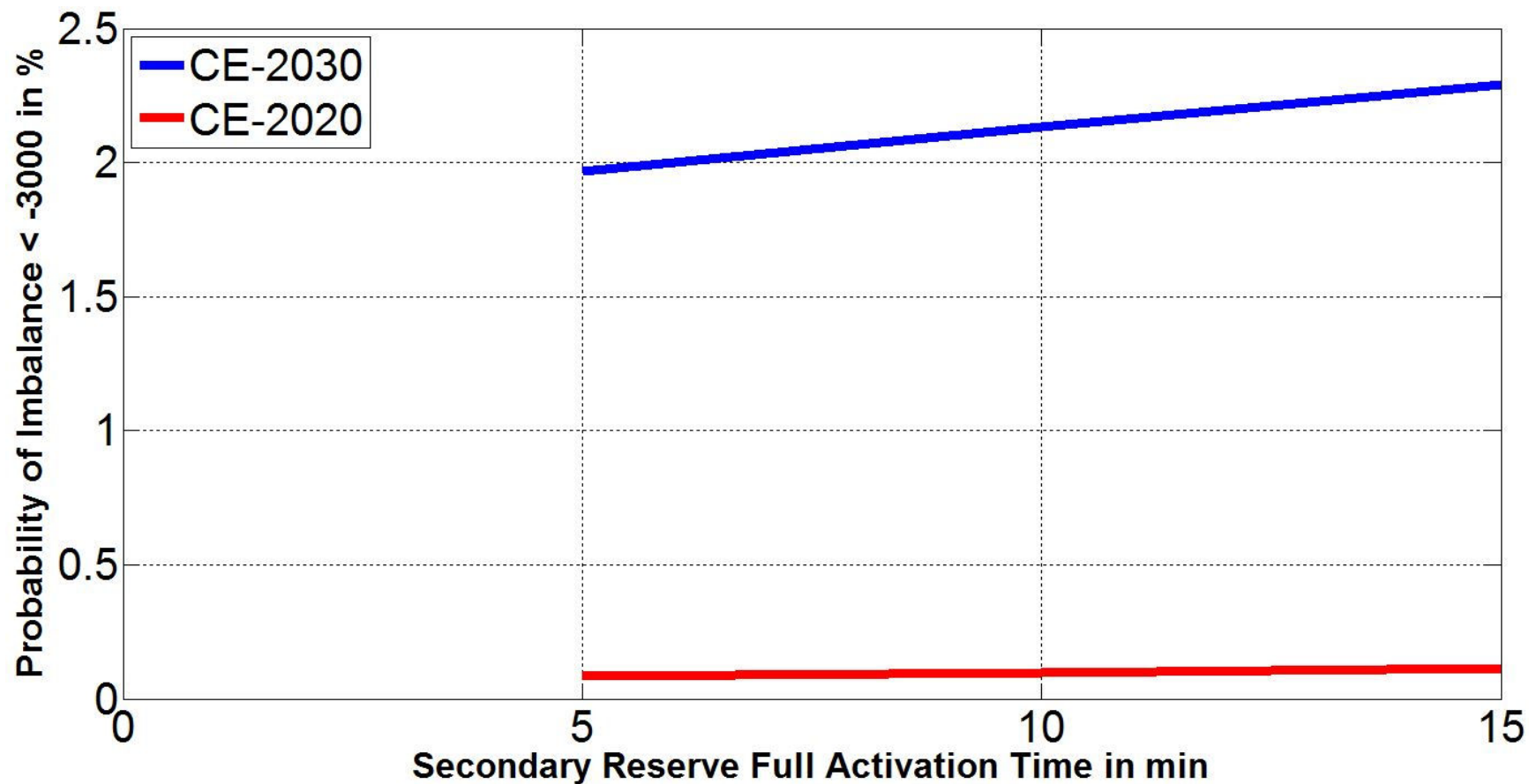
Onshore and offshore wind power development scenarios

FIG 6.1 CUMULATIVE ONSHORE AND OFFSHORE WIND POWER IN THE EU (1990-2030)

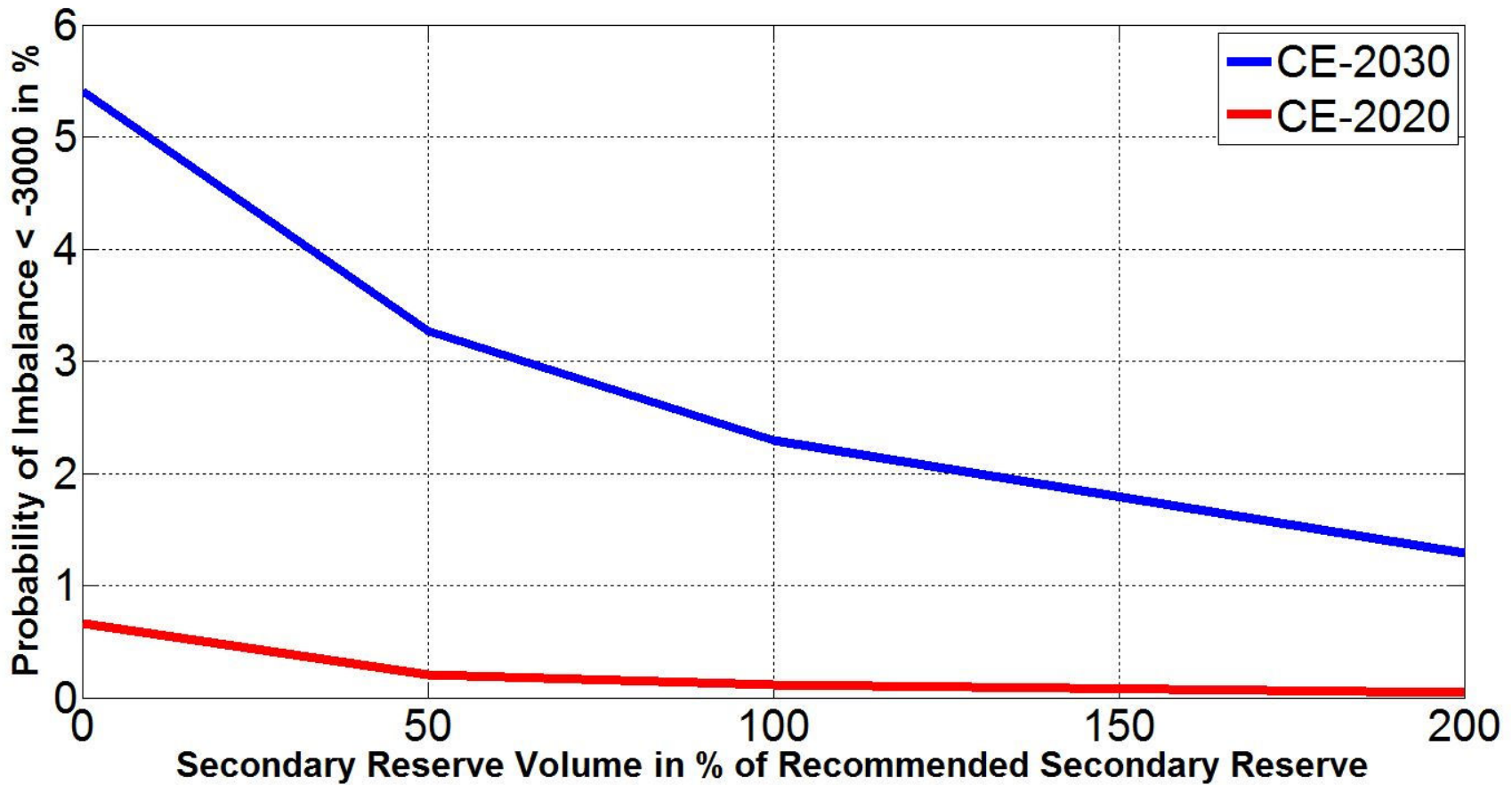


Actual: offshore 8 GW end 2014

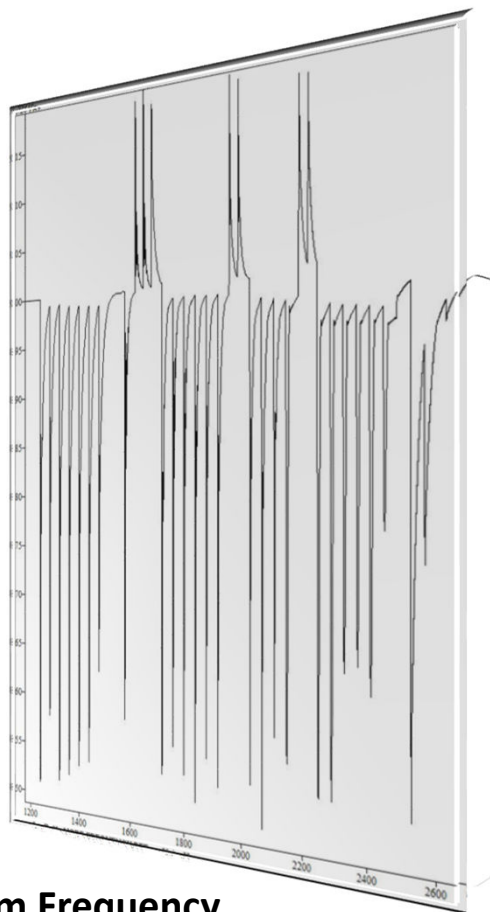
Effect of secondary reserve *response time*



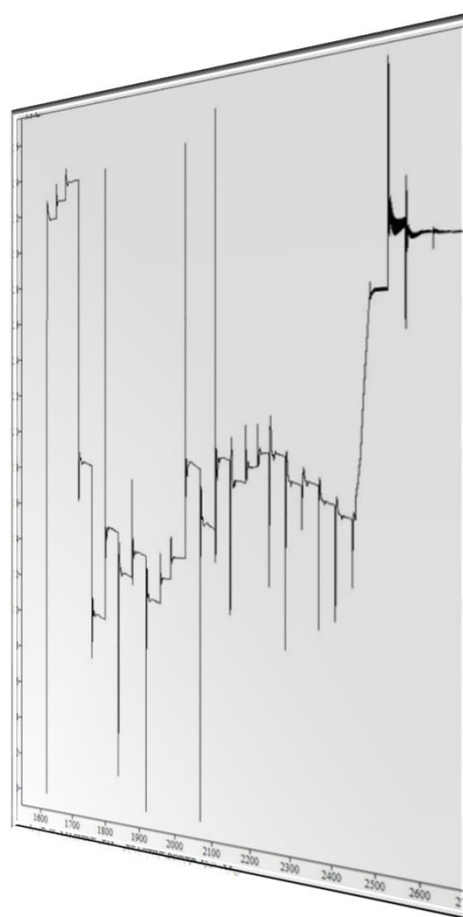
Effect of secondary reserve *volume*



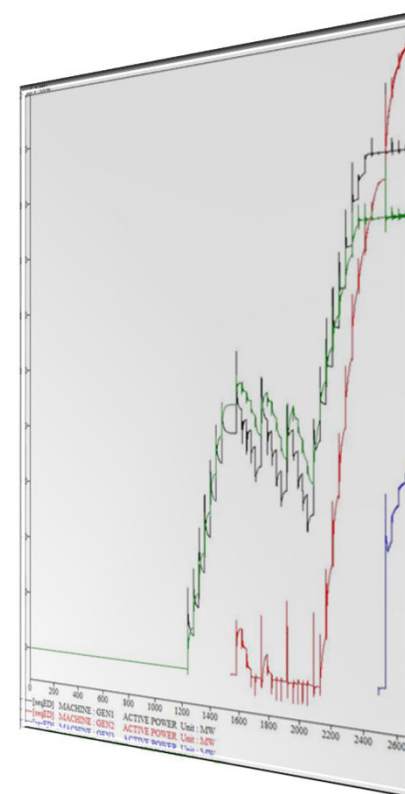
- Some results – Portuguese test case



System Frequency



Wind park Active Power



**Conventional Units
Active Power**

Conclusions & Recommendations

Simulation on a synthetic Pan-European case confirms the positive impact of ensuring wind power emergency control in overfrequency cases



Simulation of Continental European wind power scenarios in 2020 and 2030 shows that increasing the volume of secondary reserves (LFC) can contribute to reduce the risk of temporary imbalances caused by wind power uncertainties – whereas reduction of secondary reserve response time has only little impact.



Using wind power can reduce the time required for restoration of power system



Coordinated Control of HVDC & Impact of PV on UFLS Schemes

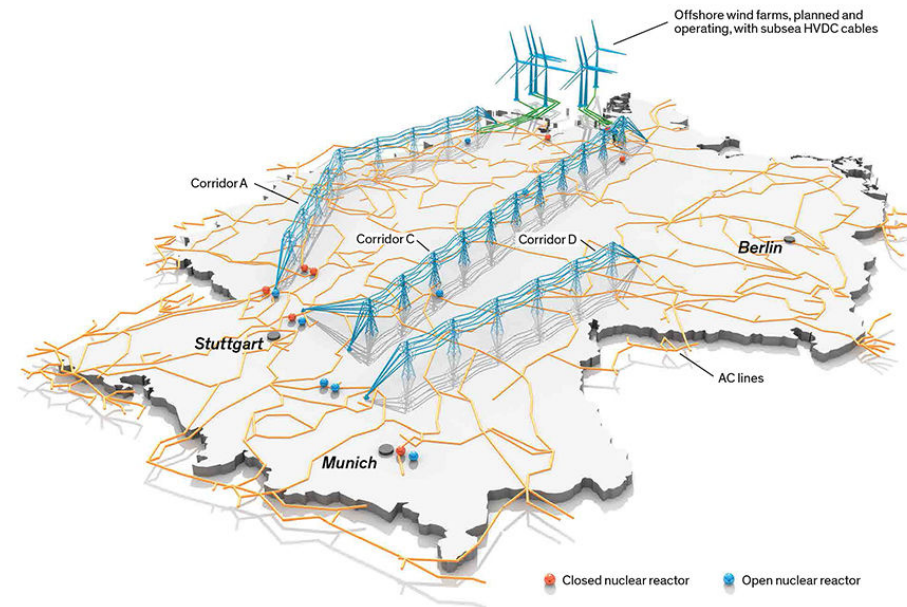
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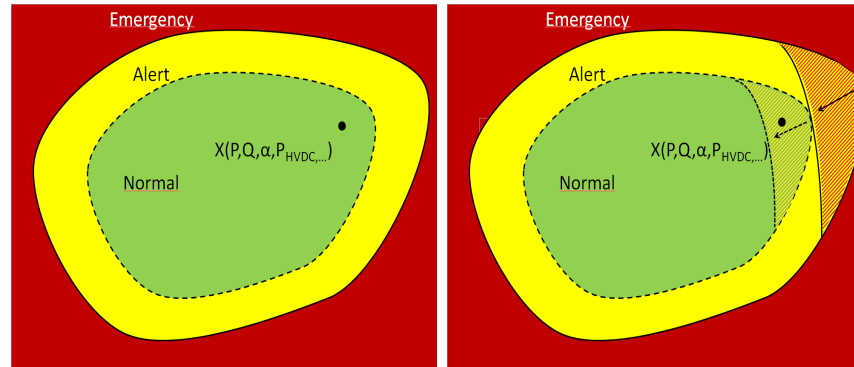
In the future power system more controllable device (PST, HVDC)

- Embedded HVDC:
 - INELFE
 - ALEGRO
 - Corridors Germany
 - UK bootstraps
 - Cobra
 - Sweden
 - ...

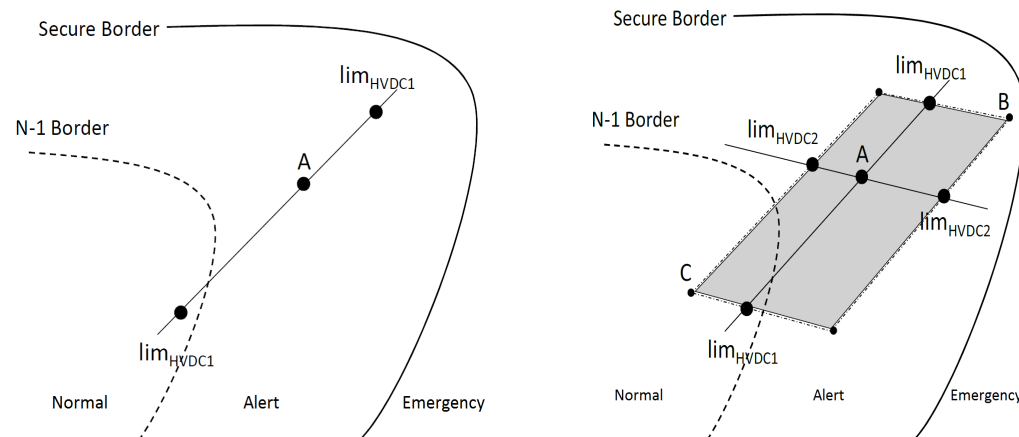


- How can embedded HVDC links contribute during emergency situations?
- Can they bring the disturbed system back to a stable operation point?
- Focus on avoiding cascading due to overloads and inter-area oscillations

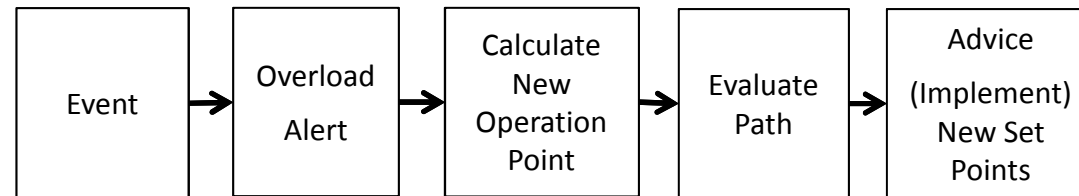
- Outage shifts the operation point to the alert or emergency state



- Coordinated control of the embedded HVDC lines allows to shift the operating point back in a larger operating space



- Tool to manage overloads and to prevent potential cascading events



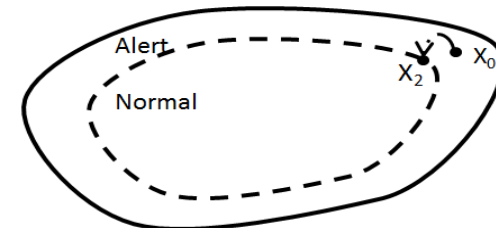
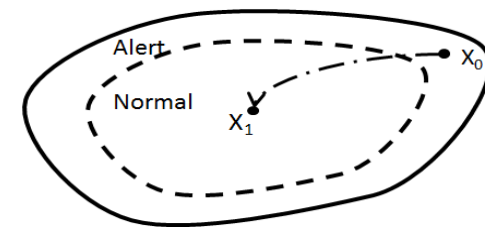
- Different objectives:

- Optimal AC branch relieve:

$$\sum_j^{\text{AC Branch}} w_j * \left(\frac{F_{j,\text{actual}}}{F_{j,\text{lim}}} \right)^n$$

- Minimal DC set-point change:

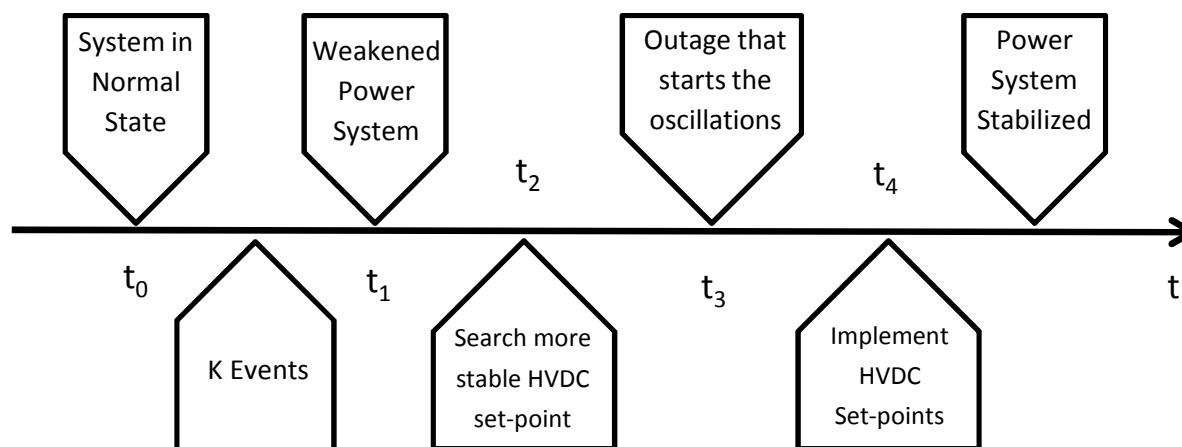
$$\sum_i^{\text{HVDC}} w_i * \left(\frac{X_{i,t} - X_{i,t-1}}{X_{i,\text{lim}}} \right)^n$$



- The tool has been implemented on a test system and successfully removed the overload avoiding a cascading in the

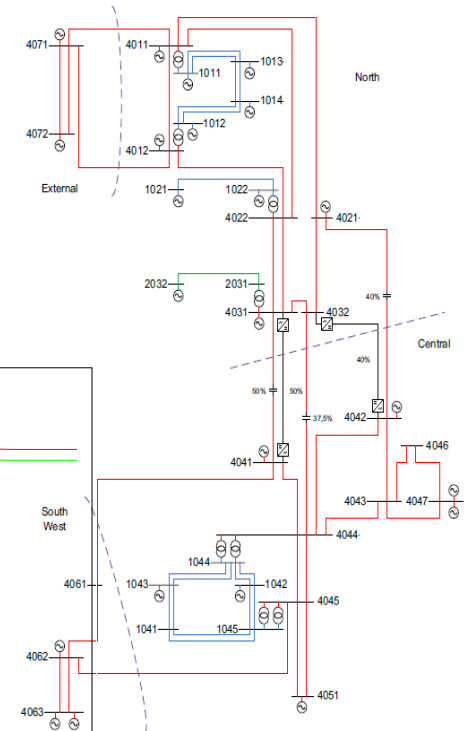
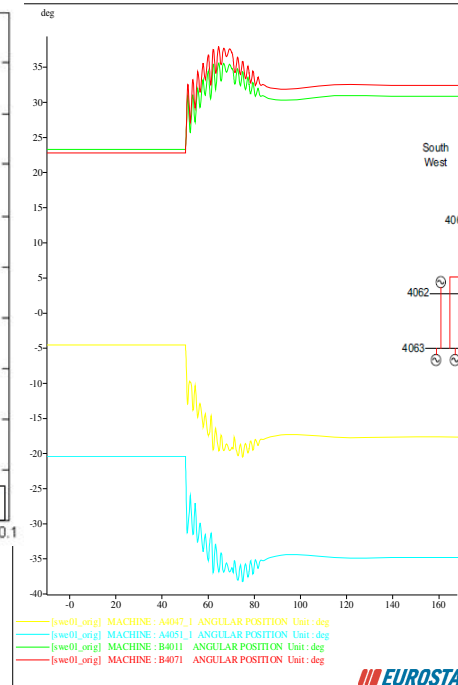
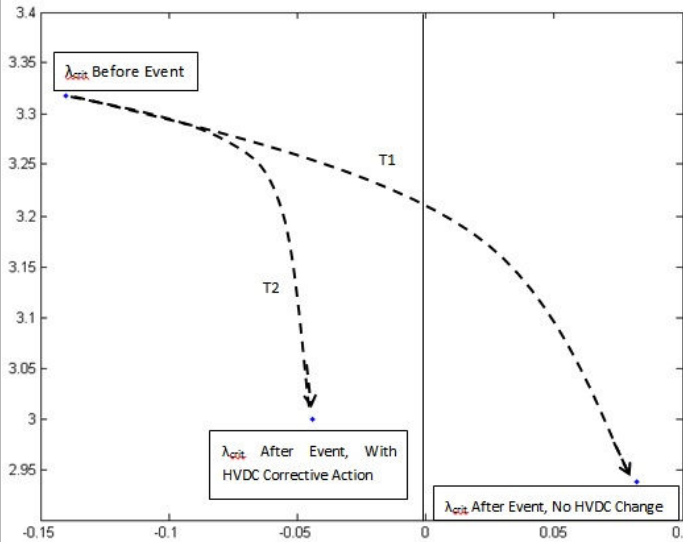
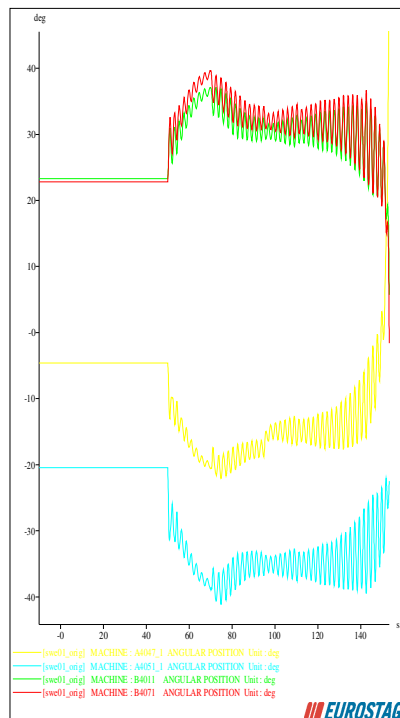
Methodology to manage inter-area oscillations with coordinated control of HVDC links

- Sequence of events and actions:



- Search the HVDC set point combination leading to the most stable operating point based on eigenvalue analysis
- Implement new set points shortly after an event when the inter-area oscillation is detected
- After stabilization move to original or more optimal set points

- The methodology has been implemented on the Nordic 32 test system and successfully stabilized an inter-area oscillation



- The potential of coordinated control has been shown on a test network
- A tool has been designed to inform and provide solutions to support operators managing overloads with embedded HVDC
- The tool has been implemented on a test system and successfully (automatically) removed overloads in the system
- A methodology to manage inter-area oscillations by coordinated control with embedded HVDC links has been proposed and successfully implemented on the Nordic 32 system

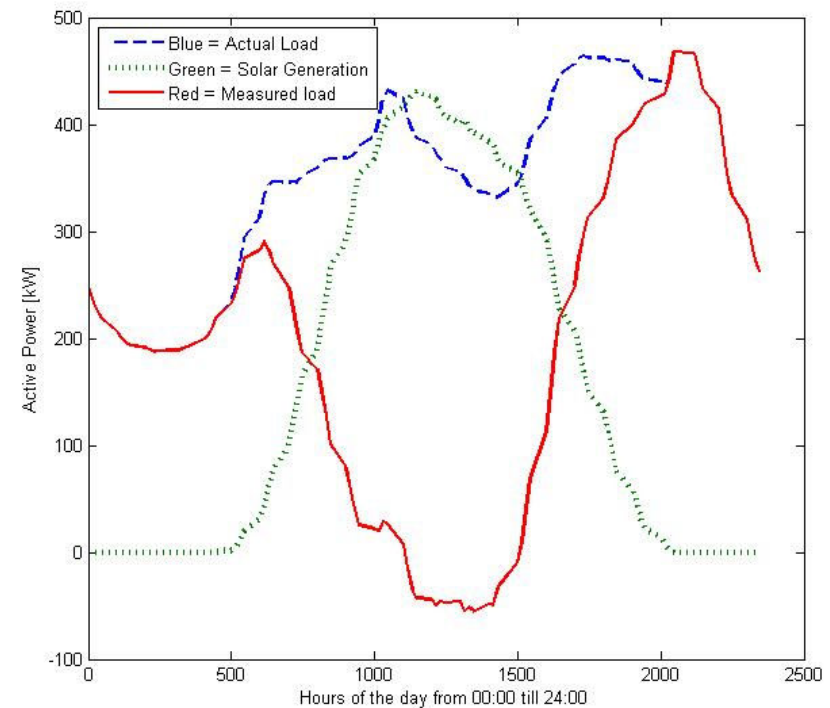
Conclusions & Recommendation

With the increased penetration of embedded HVDC links, coordinated control can contribute significantly to manage alert and emergency situations in the power system, specifically overloads and inter-area oscillations.

A tool for automatic control actions with HVDC links is developed and implemented on a test system. Such a tool is recommended as a support for operators and backup for failed control actions.

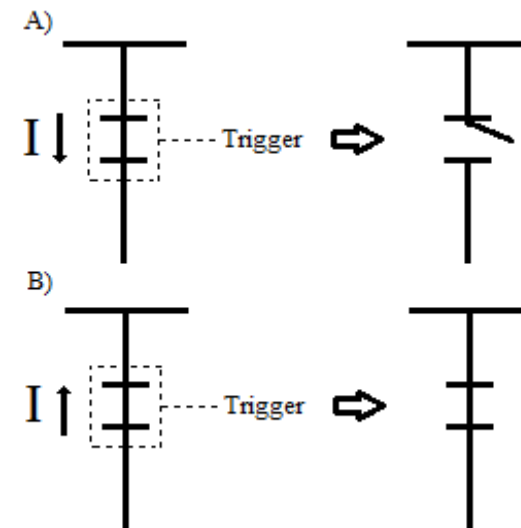
Impact of PV on UFLS Schemes

- EU targets: 34% of electricity production from renewables by 2020
 - More PV generation installed in residential areas
 - Mixed feeders behaviour:
depending on the time of the day, feeder acts
as load or generation (Example: Belgian feeder)
- UFLS scheme becomes less adequate
- New Emergency and Restoration Code
provides more harmonized scheme
design but impact of distributed
generation only limited addressed



Feeder Ranking Methods

- Business as Usual: snapshots at specific days and hours every season
 - leads to under or overestimation of the amount of load available
- Direction of Current:
Block the trip signal if the current is flowing from feeder towards the grid
 - avoid disconnection of generation
 - new measuring equipment and integration with relays needed



Feeder Ranking Methods

- Periodic Settings: Change the feeder ranking every season, month, day

Rank according to:
$$\text{Index} = \frac{\text{Installed PV Power}}{\text{Historical Measured Load}}$$

- Improved behaviour compared to BAU, but not optimal
- Better performance for smaller time window
- Hardware adjustments necessary to implement

- Smart Grid Approach: Change the feeder ranking close to real time based on measurements and estimations of PV generation

Rank according to:
$$LS_{eff} = \frac{\text{System Contribution}}{\text{Impact}_{LS\ action}} = \frac{\text{Measured Load}}{\text{Measured Load} + 2 * \text{PV generation}}$$

- More robust UFLS scheme (no generation disconnection, follow scheme design)
- Minimize consumer impact

Implementation on Data ERDF

- Smart Grid Approach (Equal percentage rank): Implement on data ERDF
 - 1300 Feeders
 - 15% of feeders has PV

| RST_load for equal percentage in each step | | | | | | | | | |
|--|------|------|------|-----|------|-----|------|------|------|
| % | 1.1 | 1.2 | 2.1 | 2.2 | 3.1 | 3.2 | 4 | 5 | |
| 1.1 | 7.7 | 0 | 0 | 0 | 0.1 | 0.9 | 0 | 0 | 8.7 |
| 1.2 | 2.5 | 6.6 | 0 | 0 | 0.8 | 0.6 | 0 | -0.1 | 10.4 |
| 2.1 | 0 | 3.5 | 4.9 | 0 | 0.6 | 0.5 | 0 | -0.1 | 9.4 |
| 2.2 | 0 | 0 | 5.2 | 2.5 | 1 | 0.7 | 0 | 0 | 9.4 |
| 3.1 | 0 | 0 | 0 | 7.1 | 0.4 | 0.3 | 0 | -0.1 | 7.7 |
| 3.2 | 0 | 0 | 0 | 0.4 | 7.2 | 1.4 | 0 | 0 | 9 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 18.2 | -0.3 | 17.9 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27.4 | 27.4 |
| | 10.2 | 10.1 | 10.1 | 10 | 10.1 | 4.4 | 18.2 | 26.8 | |

Results

- UFLS scheme becomes less adequate due to integration of DG
- Different ranking methods have been proposed and analysed
- A test on the data infrax showed the potential of the different methods
- A test on the data of ERDF of 2012 showed that the smart grid approach improves the robustness of the UFLS scheme while reducing the consumer impact

Conclusions & Recommendation

The robustness of current UFLS schemes comes under pressure from the increased penetration of distributed generation.

Different feeder ranking methods have been designed and successfully implement on power system data of different DSOs. The scheme robustness can be improved, while reducing consumer impact. Therefore it is recommended to use methods which take distributed generation into account for the feeder ranking in UFLS schemes

Thank you!

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Out-of-Step (OOS) Relay Tuning

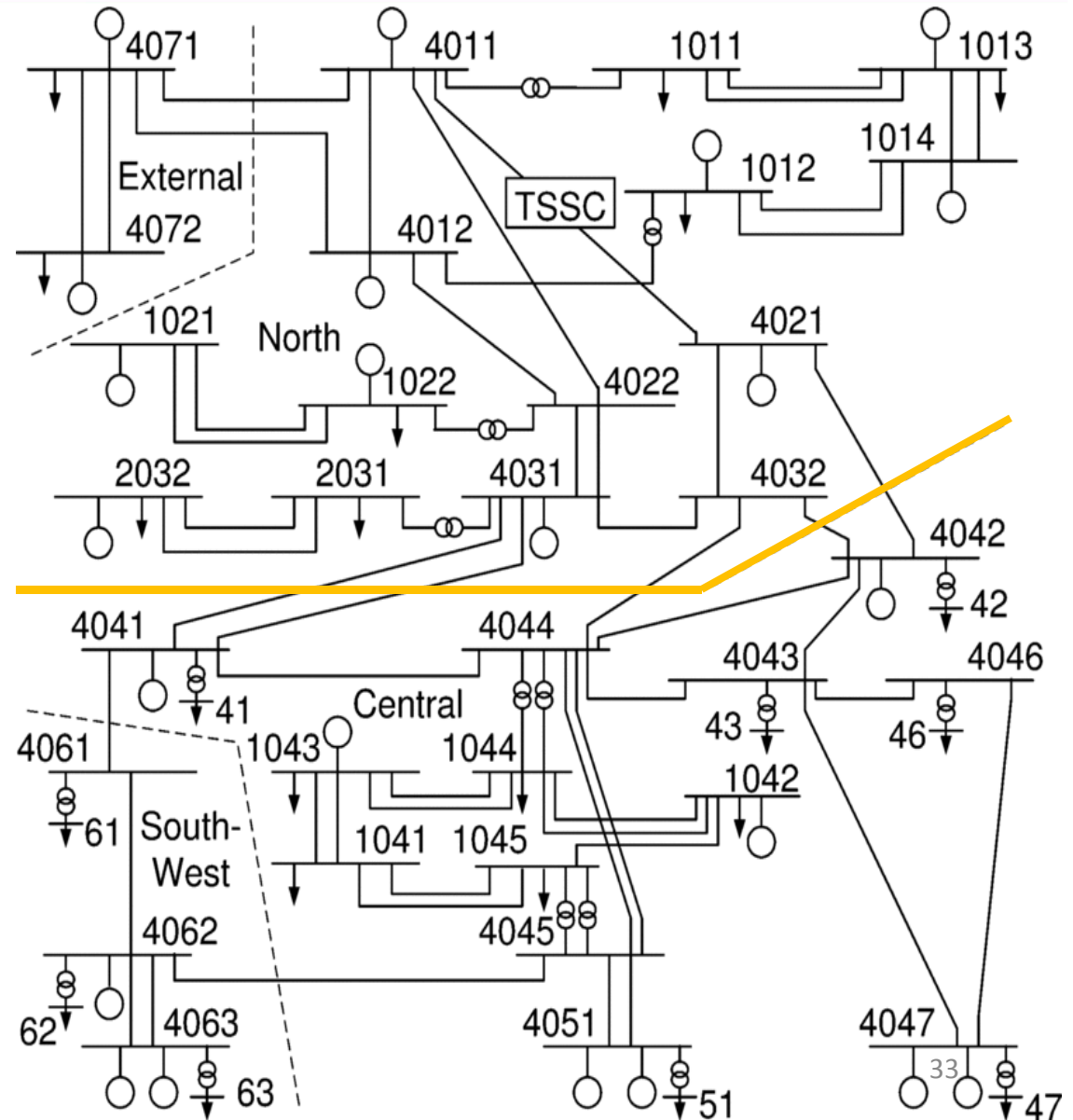
Stijn COLE

stijn.cole@gdfsuez.com

Out-of-step

Out-of-step relay (loss of synchronism relay)

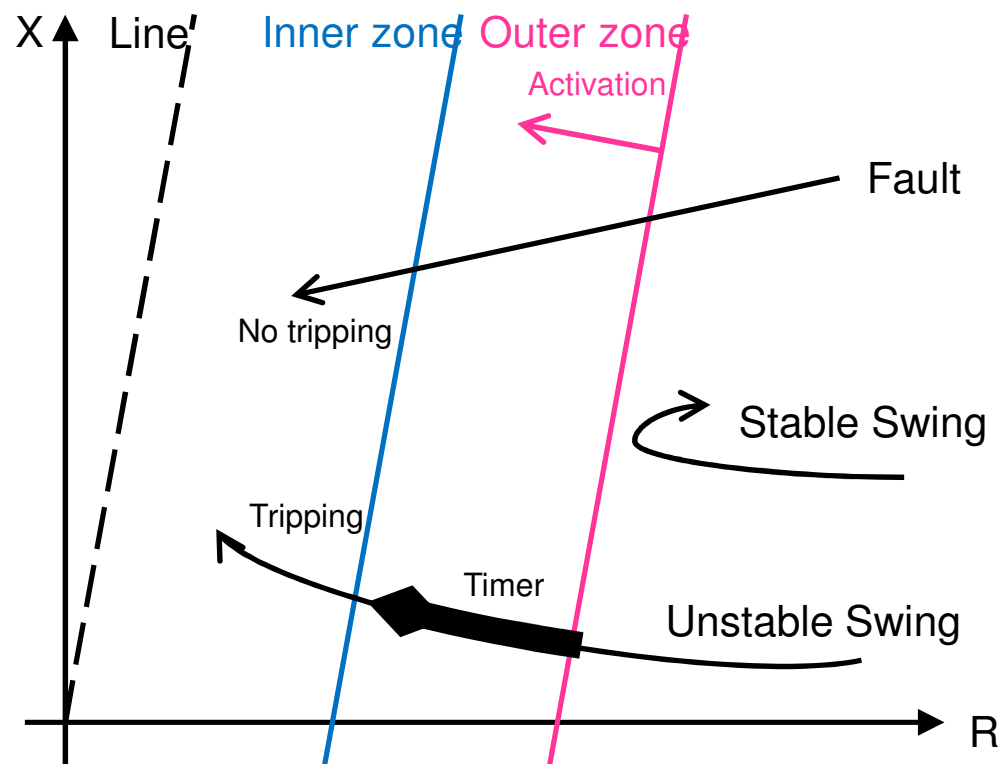
- Detects out-of-step conditions in the power system
- Sends signals to the correct breakers to split the system



OOS relay principles

Out-of-step relay (loss of synchronism relay)

- Discriminate between faults, stable swings, and unstable swings
- Based on inner and outer zone setting, and timer



Methodology

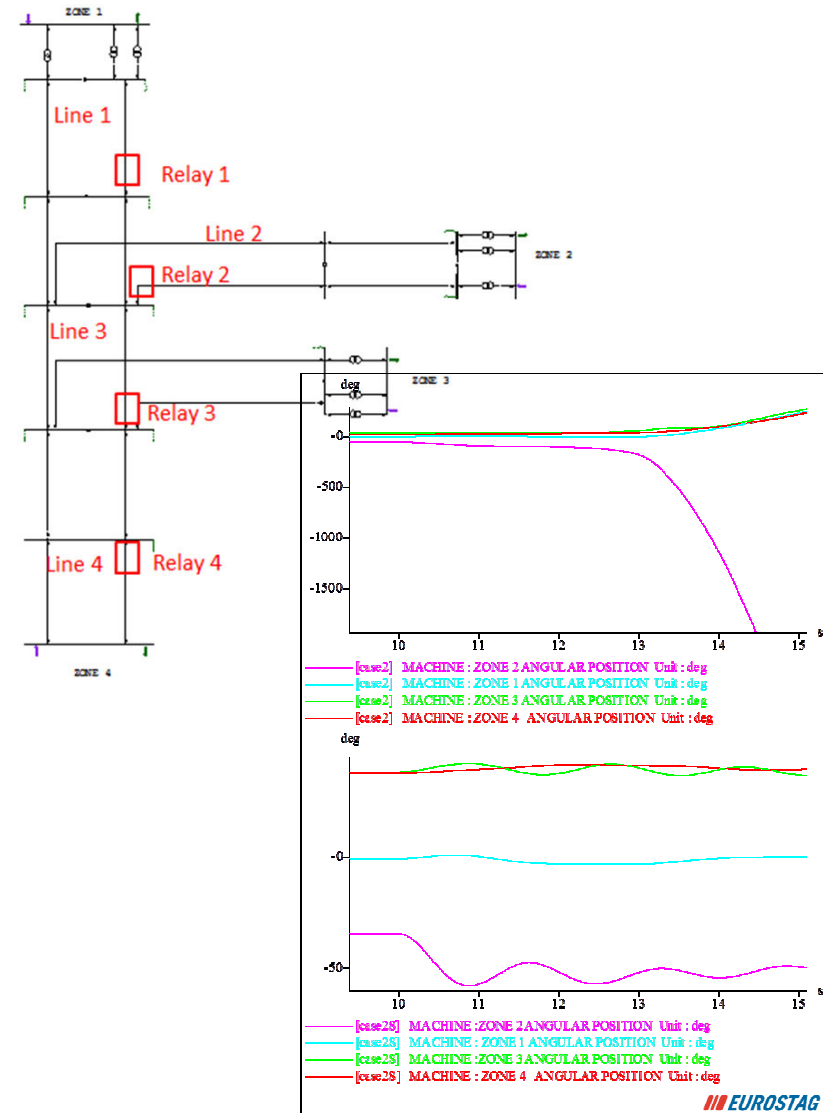
- Target trip matrix
 - Indicates the relays that are expected to trip for each of the simulated incidents
- Achieved trip matrix
 - Indicates the relays that would effectively trip for each of the simulated incidents

| | Incident 1 | Incident 2 | ... | Incident M |
|----------------|-------------------|-------------------|-----|-------------------|
| Relay 1 | Not tripping | Not tripping | ... | Not tripping |
| Relay 2 | Not tripping | Not tripping | ... | Tripping |
| ... | ... | ... | ... | ... |
| Relay M | Tripping | Not tripping | ... | Tripping |

- Tune relay parameters to minimize the difference between target and achieved trip matrix
- Minimize the
 - tripping failure: OOS not activated when it should have
 - spurious tripping: OOS activated when it should not have

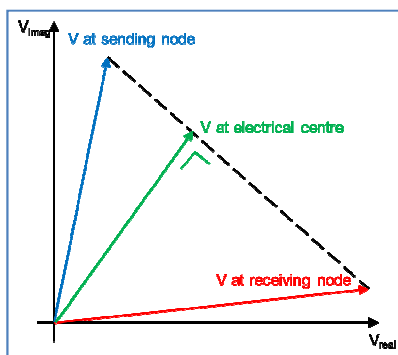
Tuning of OOS relays

- A tool for automatic tuning of OOS relay parameters was developed based on mathematical optimisation
- A test on the Nordic32 system with one relay showed that the tool found a better solution than the manual solution
- A test on a system with four relays showed the capacity of the tool to tune several relays simultaneously

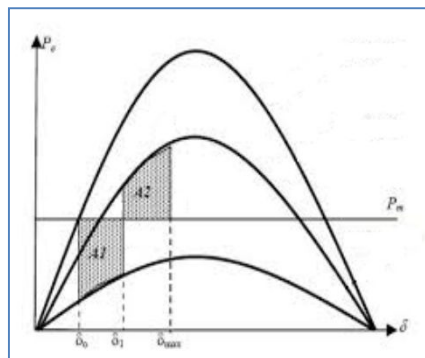


Use of PMU information

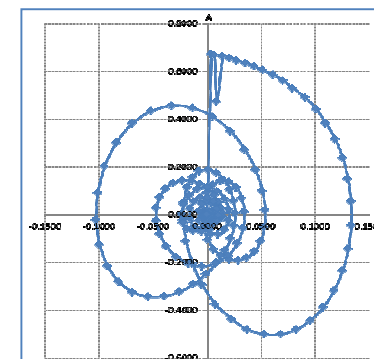
- Several ways of using PMU information have been implemented and tested
- Some of them are promising
- There are drawbacks (non-standard relay models, tuning more difficult, filter cases of spurious tripping,...)



Direct calculation
of V at electrical
centre



Monitoring rotor
angle dynamics



Extrapolation of
rotor angle curve

Conclusions & Recommendations

A tool for automatic tuning of out-of-step relay parameters is developed and successfully tested on realistic power systems. It is recommended to use such automatic tools as the results obtained are better than with manual tuning.

Use of PMU information in OOS relays is promising, but more research is needed before a recommendation on the use of PMU for OOS relays can be made.

Thank you

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