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Interarea oscillations in Continental Europe: Analysis of 1st December 2016 event

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Continental Europe synchronous Area / RTE

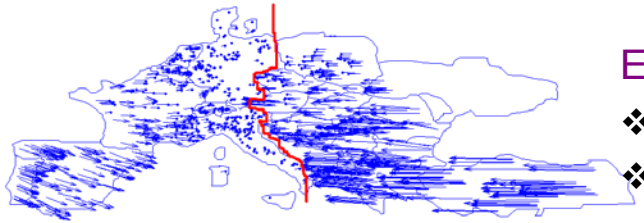
Continental Europe

- Installed Generation~970 GW
- Annual load~3000 TWh
- Peak load ~ 500 GW

RTE

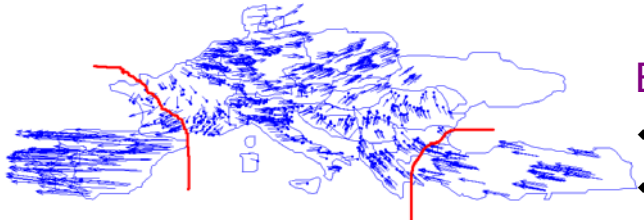
- 100 000 km of lines
- Nominal voltages 63-400 kV
- 8500 employees

3 main inter-area modes



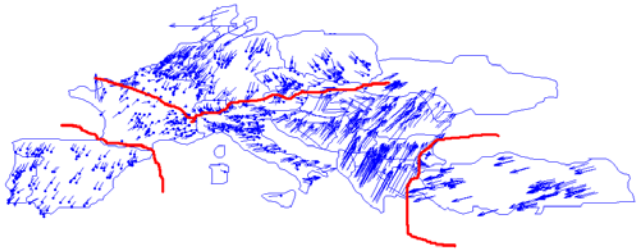
East-West mode

- ❖Frequency ~ 0.15 Hz
- ❖Damping : good



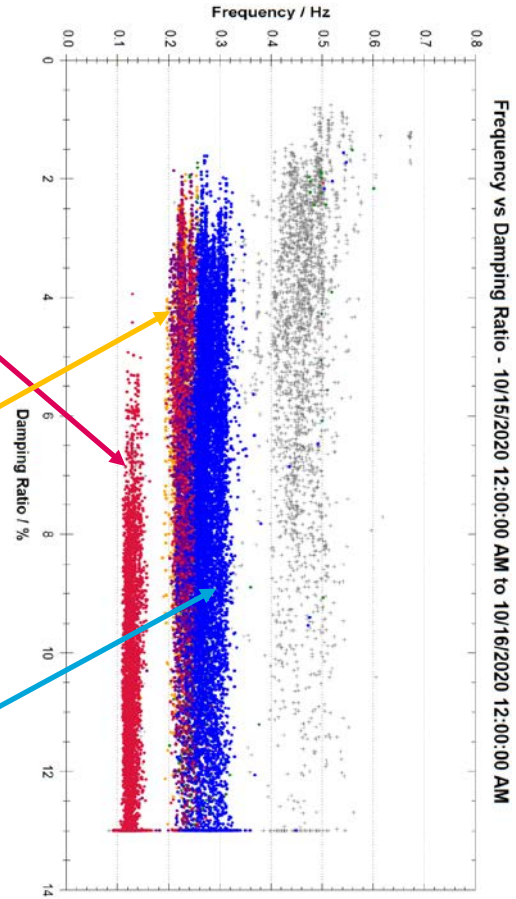
East-Center-West mode

- ❖Frequency ~ 0.22 Hz
- ❖Damping : can be low



North-South mode

- ❖Frequency ~ 0.3 Hz
- ❖Damping : can be low



2 last « big » events

East-Center-West mode

- 01 December 2016
- Ref : *ENTSOE – Analysis of CE inter-area oscillations of 1st December 2016*

https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/CE_inter-area_oscillations_Dec_1st_2016_PUBLIC_V7.pdf

North South mode

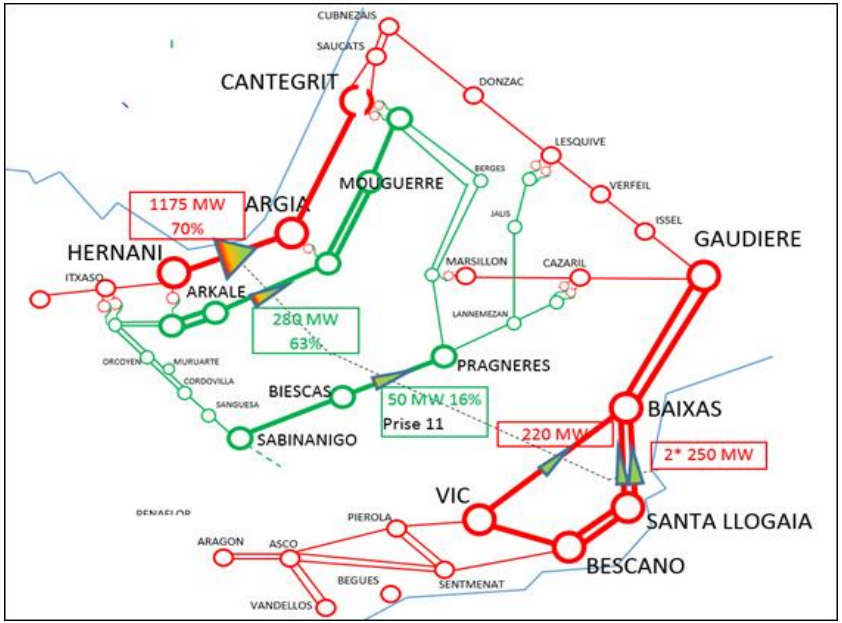
- 03 December 2017
- Ref : *ENTSOE - Oscillation Event 03.12.2017*

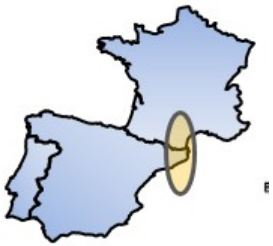
https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/Regional_Groups_Continental_Europe/OSCILLATION_REPORT_SPD.pdf

Description of the event

Preliminary situation

Before disturbance:
High import from Spain to France : ~ 2300 MW
Exchange Portugal to Spain : 3000 MW



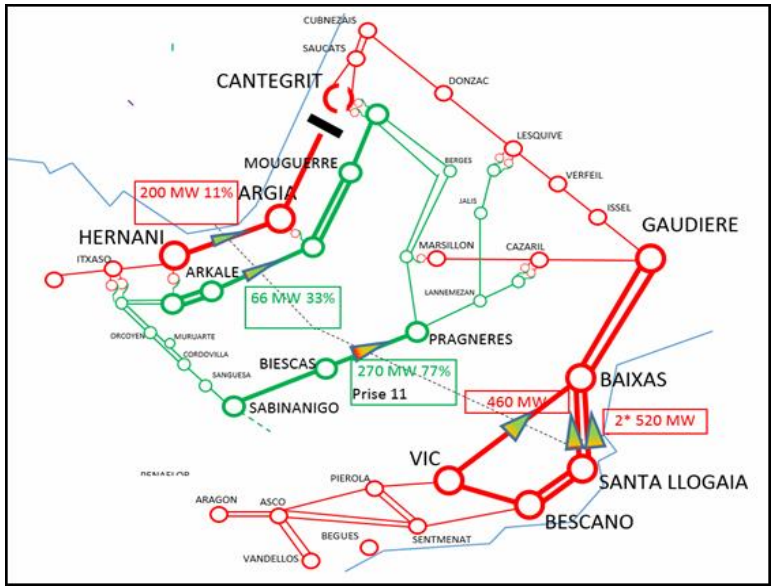


Disturbance

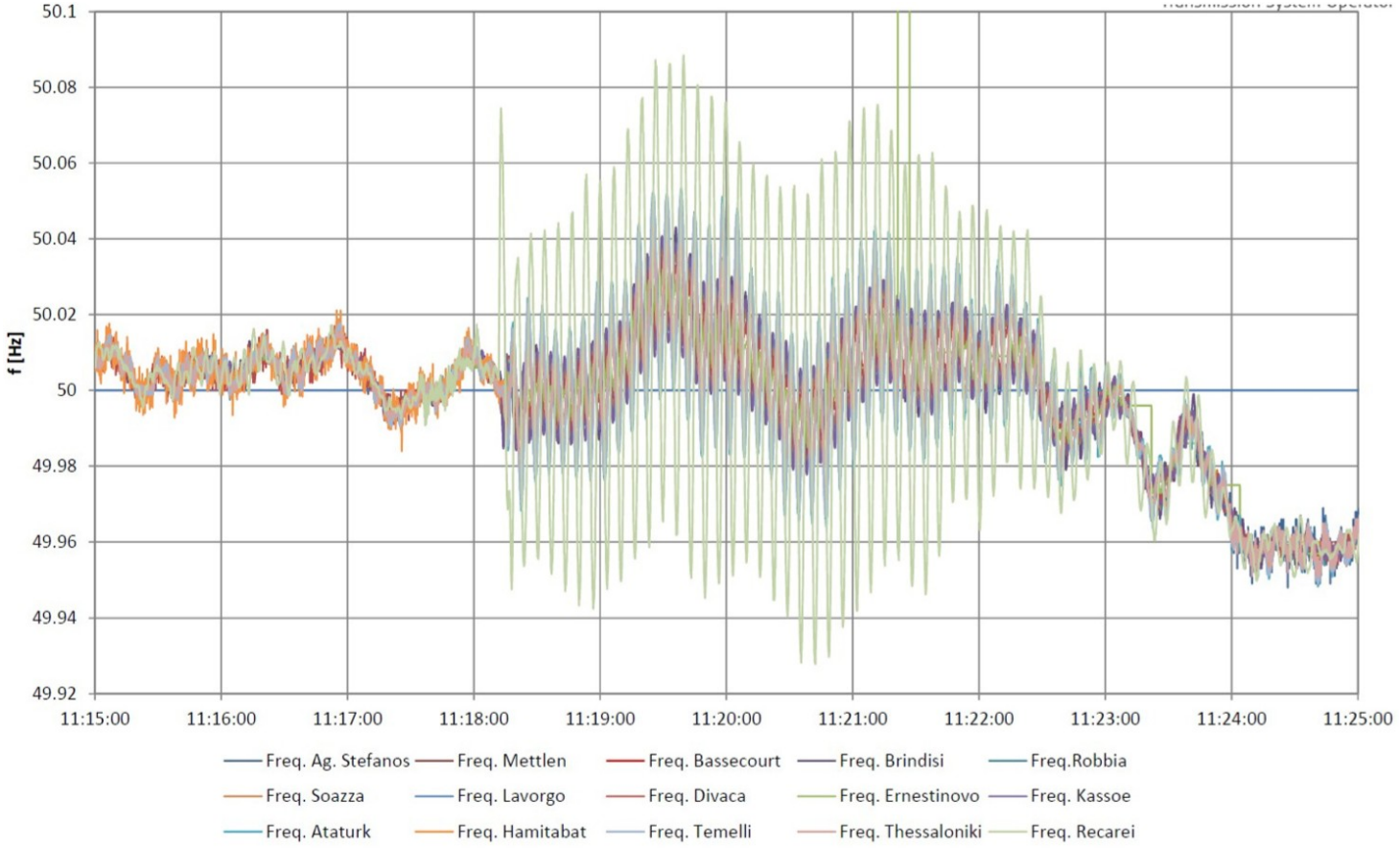
Event: At 11h18, unexpected opening of the circuit breaker (without fault) at Cantegrit substation => Argia-Cantegrit tripping

Impact on the network :

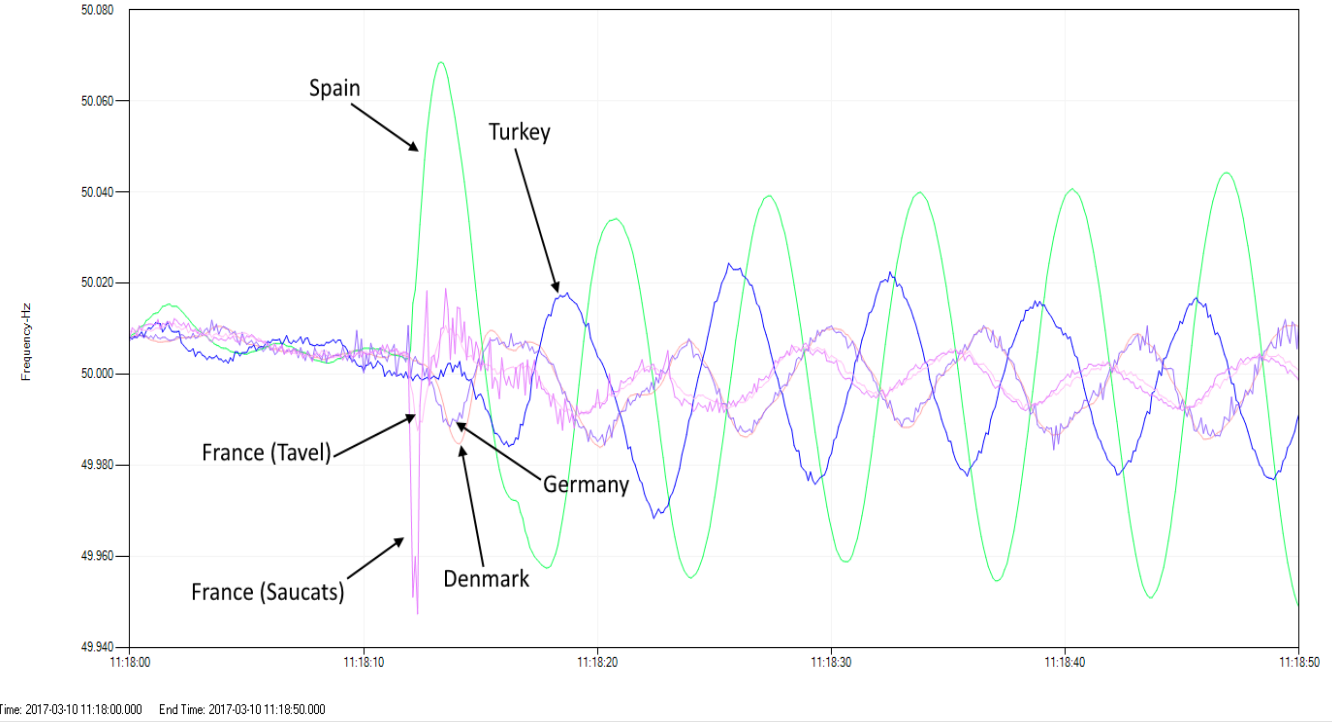
- Static situation is ok
- Low frequency power oscillations



Oscillations on the European Network…

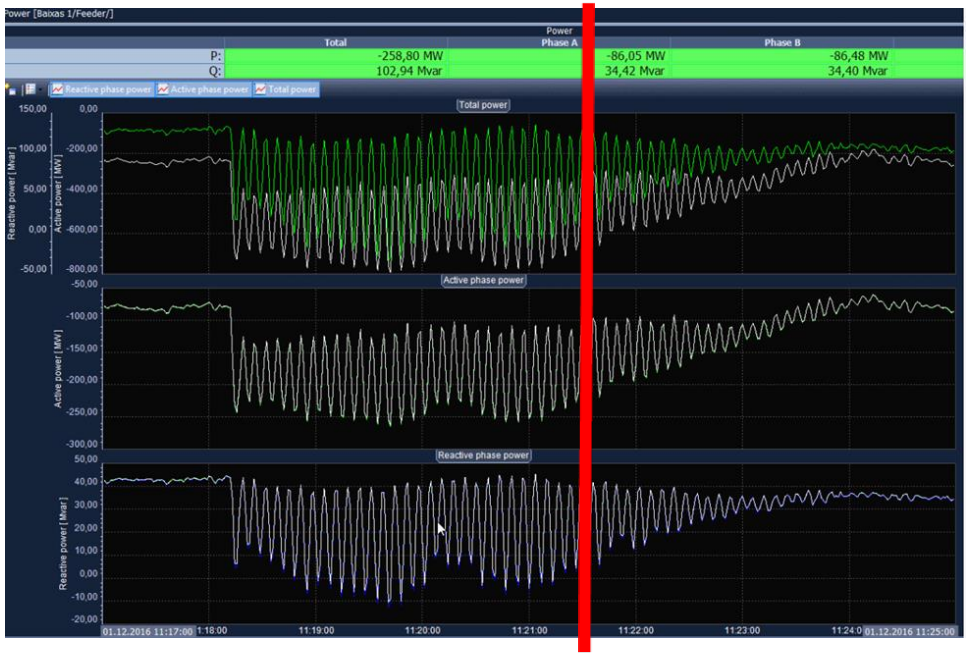


...undamped oscillations



Dispatchers action

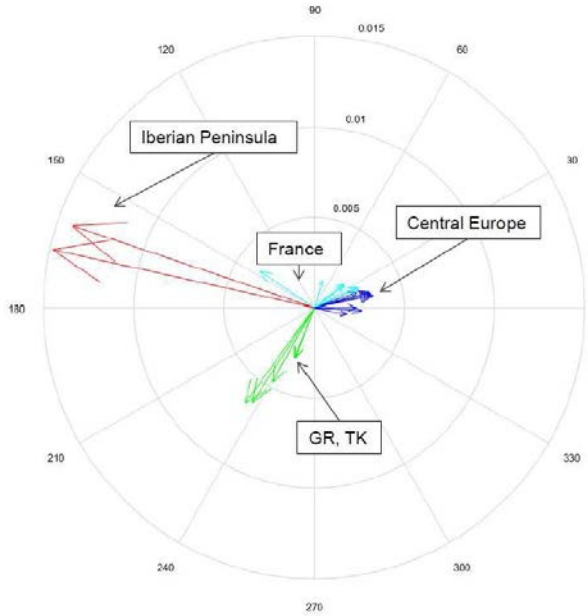
11h21 : reduction of the Spain to France schedule from 2250 MW to 1000 MW to restore N-1 security



Measurements in France- Spain HVDC links where the oscillations were also observed

Analysis of the event

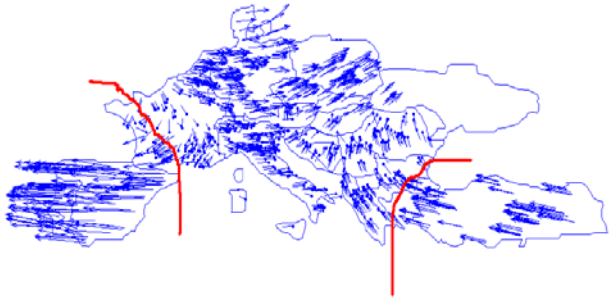
RTE and REE studies



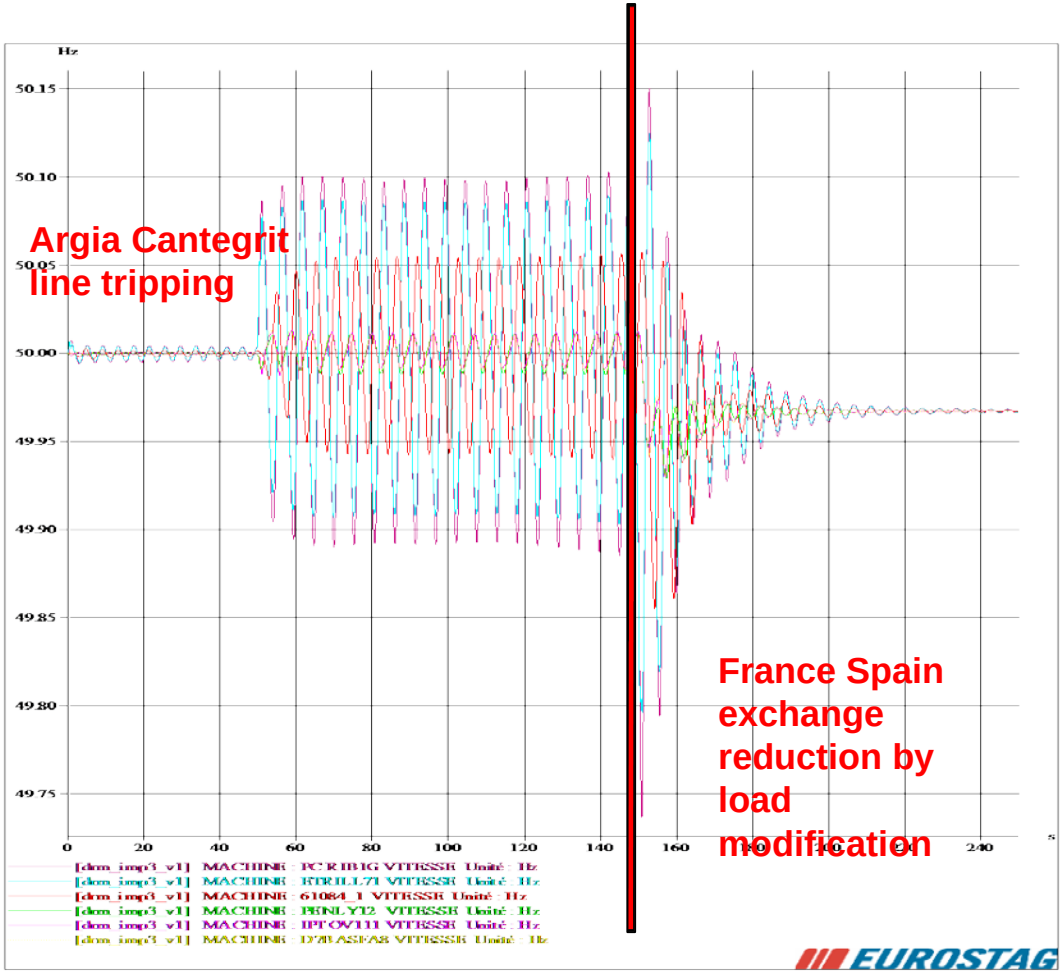
DATA COLLECTION : Reproduce the event on simulation tool

MODAL ANALYSIS :
Iberian Peninsula oscillated in phase opposition to the rest of
Continental Europe and around 70° degrees against Turkey and Greece.

COMPARISON PMU & SIMULATION



RTE: RESULTS WITH THE DYNAMIC REFERENCE MODEL (DRM)



-PINK : ITALY

-PURPLE : PORTUGAL

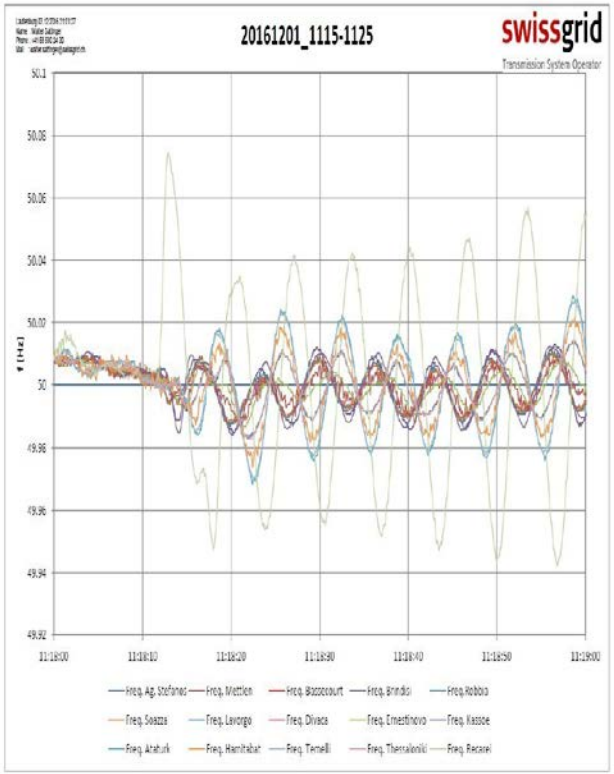
-BLUE : SPAIN

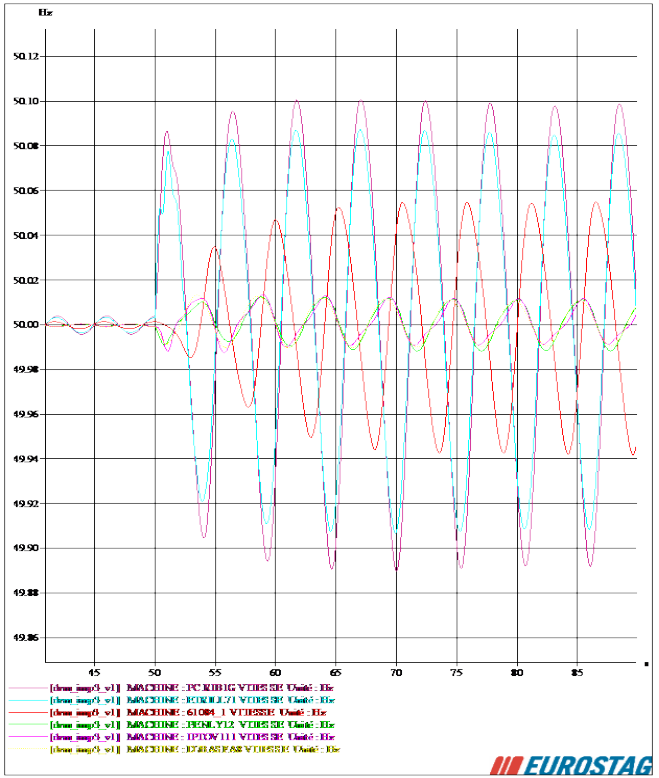
-RED : TURKEY

-GREEN : FRANCE

-YELLOW : GERMANY

Comparison between PMU recordings and DRM simulation





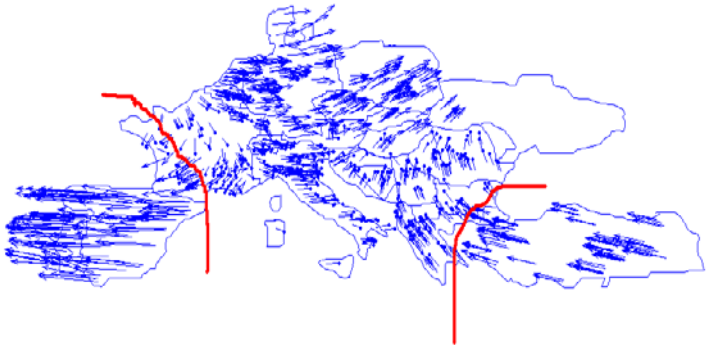
The observed inter-area mode (East-Centre-West mode) is accurately reproduced by the non-linear time domain simulation with the DRM

RTE Studies

The high flows from Spain to France have a negative impact on the damping

From simulation :

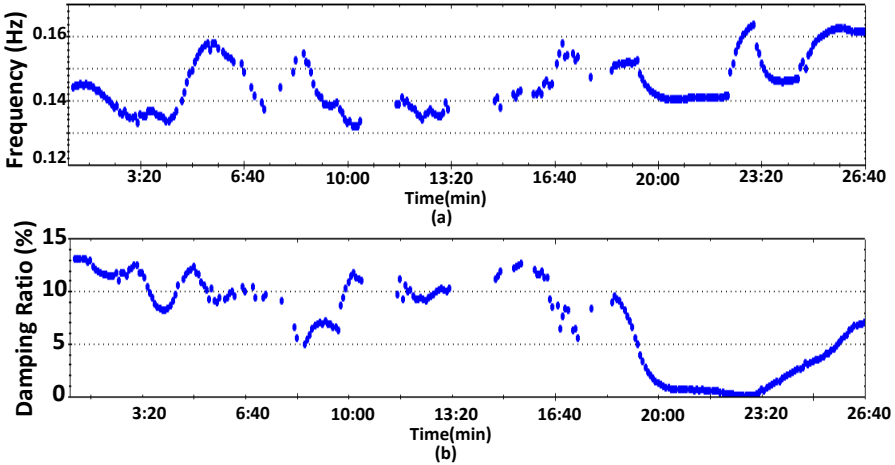
Active power exchanges France to Spain	Damping of the West-Center-East mode (~ 0,22Hz)
2800 MW	17,09 %
1400 MW	15,64 %
- 850 MW	8,47 %
-2800 MW	5,68 %

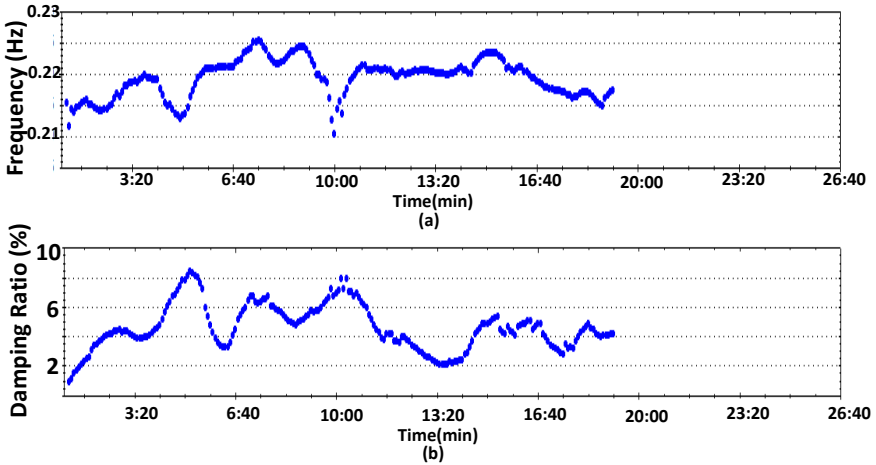


On the real system, the relation is not as straight forward because we can have export from France to Spain with a low damping

Analysis using PMU data

Ambient model analysis using FFDD



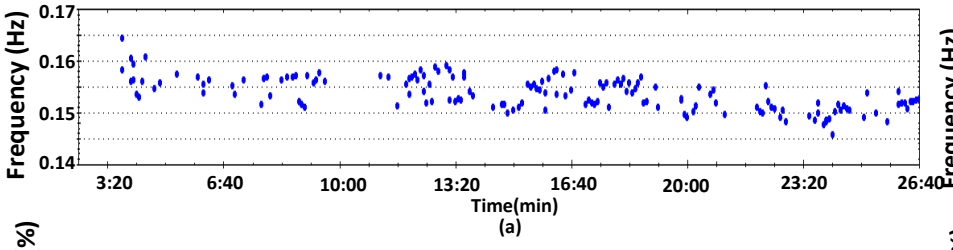


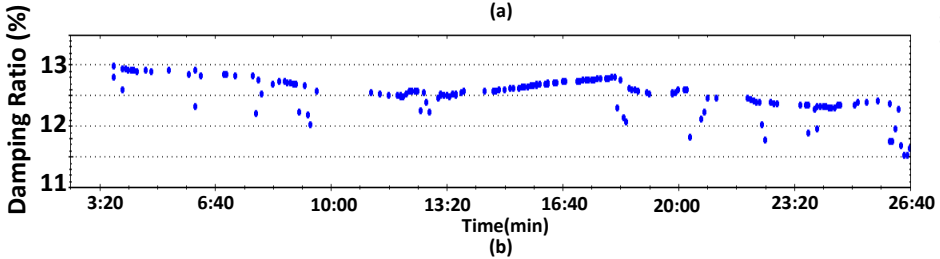
0.15 Hz mode damping drops down to zero during the event. Then recovers.

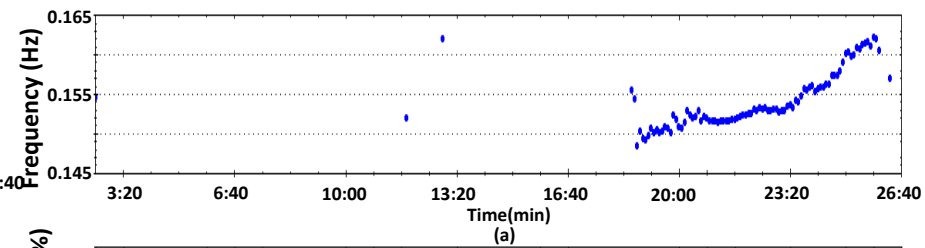
Two different modes present near 0.14 Hz.

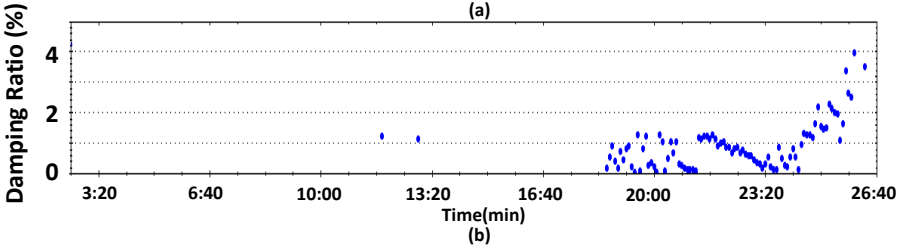
0.22 Hz mode disappears at the start of the event. Changes to 0.14 Hz mode.

Ambient model analysis using FSSI





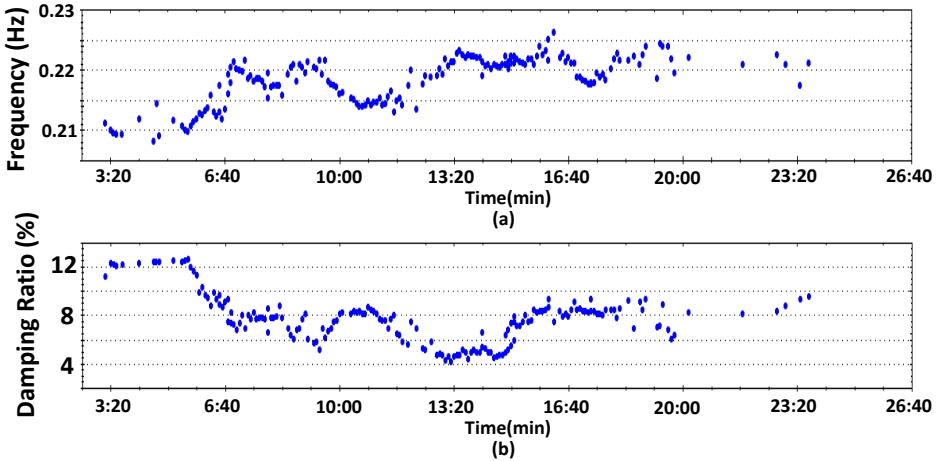


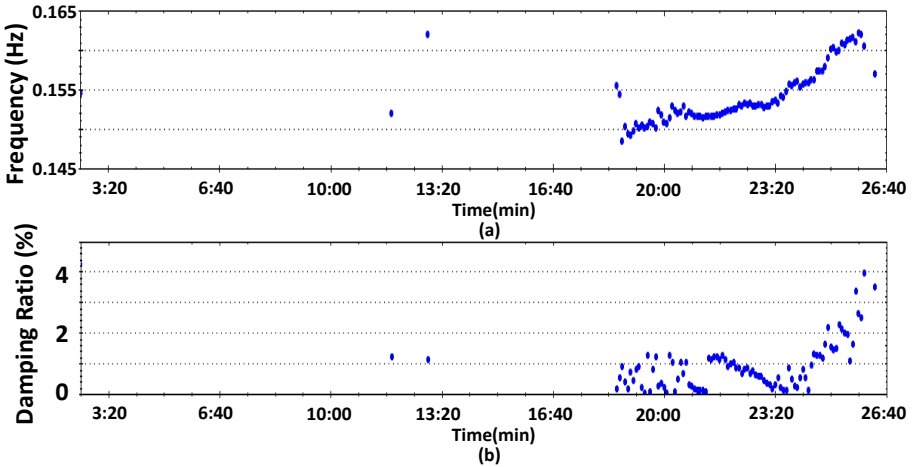


There is a well-damped 0.15 Hz mode that does not change during the event.

A second poorly damped 0.15 Hz mode appears at the start of the event.

FSSI shows abrupt change in mode freq and damping at the start of the event





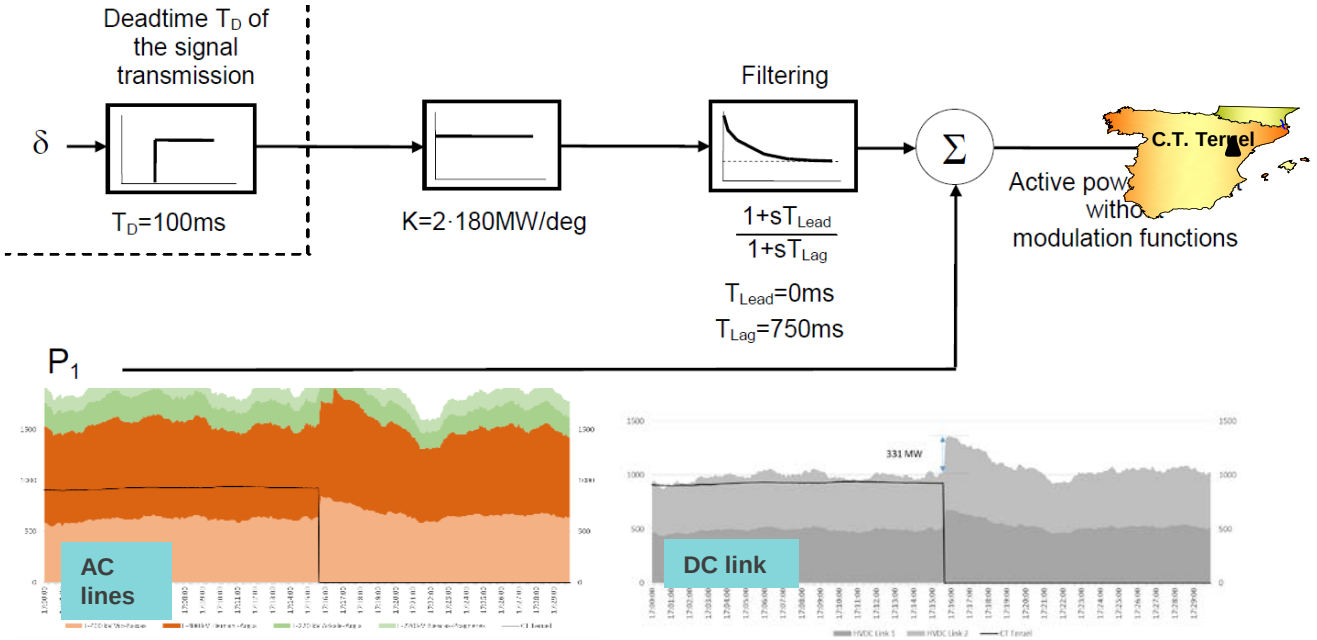
0.22 Hz mode disappears at the start of the event.

Poorly damped 0.15 Hz mode appears at the start of the event.

Impact of HVDC active power control

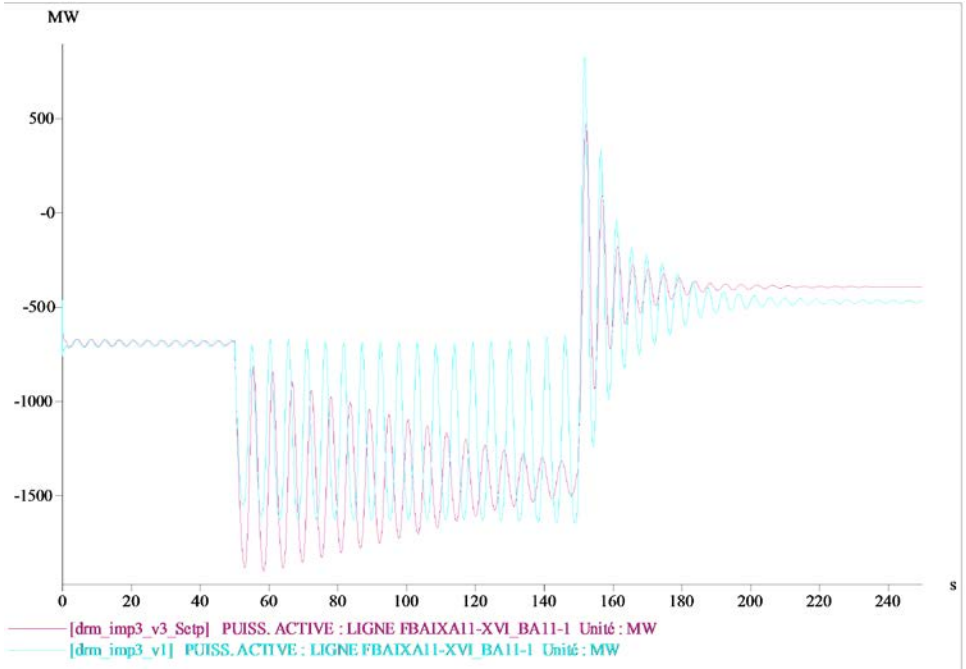
HVDC operational mode : AC emulation

$P_{VSC} = K * (\delta_{BAIXAS} - \delta_{StLlog})$: interesting for static operation



HVDC: setpoint vs AC emulation ?

The operation mode of the HVDC has an impact on the damping



Active power in parallel AC line

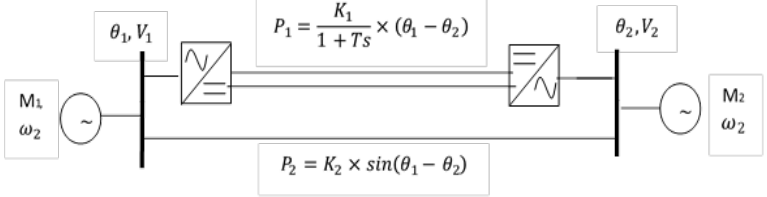
Red curve : HVDC link in setpoint mode

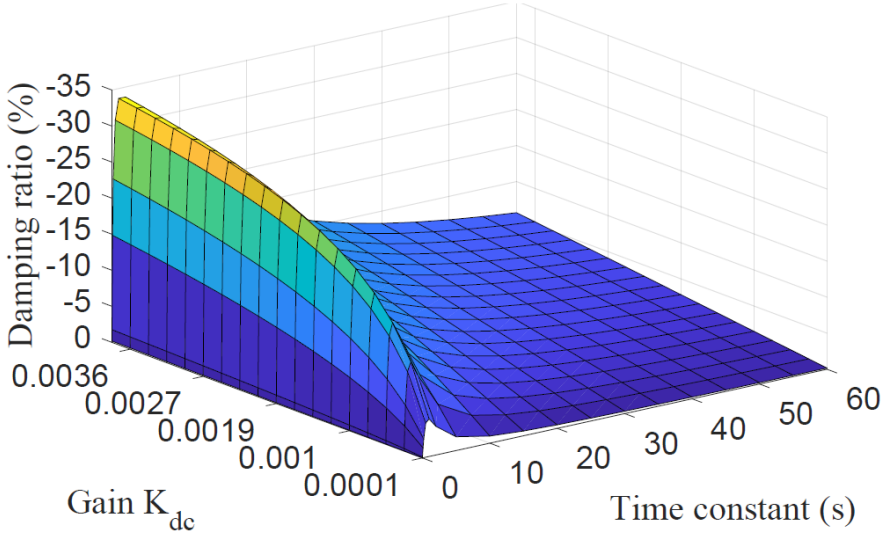
Blue curve: HVDC link in AC emulation mode

AC emulation mode: theoretical analysis

INAPPROPRIATE GAIN AND FILTERING PARAMETER HAVE A NEGATIVE IMPACT ON SMALL SIGNAL STABILITY

$$P_{HVDC\_theoritical} = K_1 \times (\theta_1 - \theta_2)$$

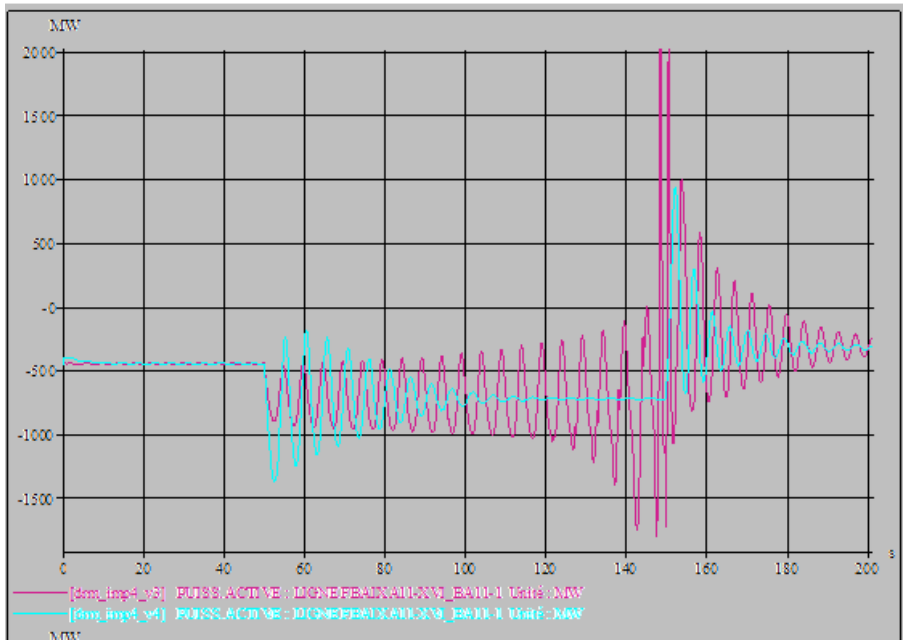




Ref : IEEE publication in 2019 : « Small Signal Stability Analysis of the Angle Difference Control on a HVDC Interconnection Embedded in the CE Synchronous Power System *»*

Improve AC emulation

The filtering time of the emulation has an impact on the damping



Conclusion : Increasing the time constant of AC emulation improves the damping ratio of the East-Centre-West mode

AC emulation (current mode, filter time constant = 750 ms)
AC emulation with filter time constant = 25 s

AC emulation slowering

Common studies between REE and RTE :

Trade-off oscillation damping/dynamic performance ➔ τ =50 s.

Small signal stability	☑
Transient stability	☑
Power flow security analysis	☑
Load encroachment on protections	☑

τ =50 s validated

Slowering tested on HVDC replicas before implementing it in the field (january 2019) by REE and RTE

Ref : CIGRE session paper 2020 B4-130 “Improvement of the oscillatory behaviour of the HVDC link between Spain and France”

Conclusions & next steps

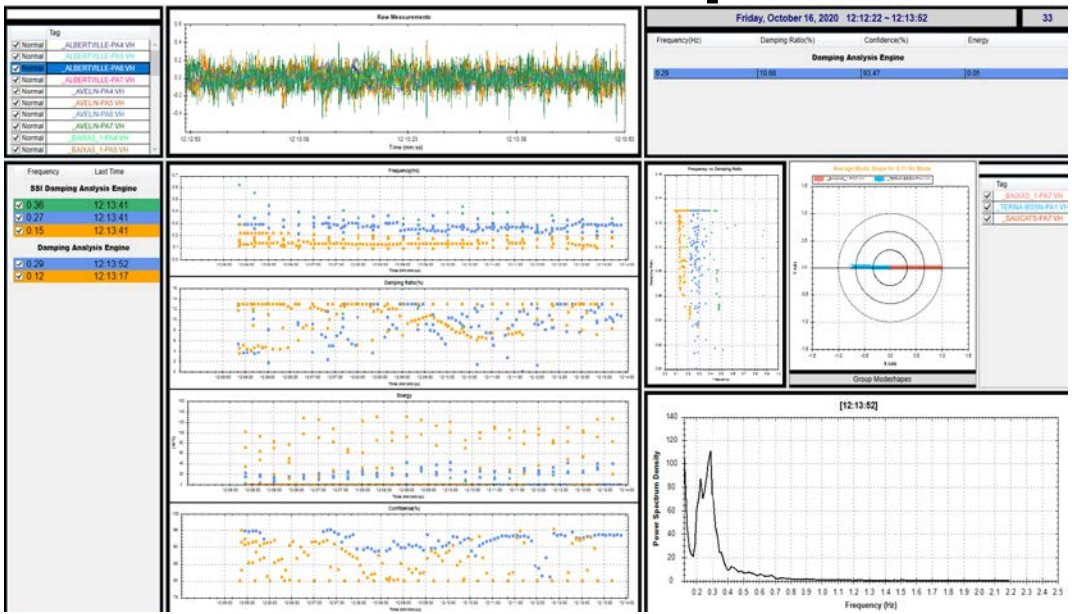
CONCLUSIONS

The event demonstrates that coincidence and combination of different factors can influence the system stability. Each factor may not normally be critical itself but in this particular scenario the combined effect decreased the general damping.

- Aspects such as HVDC influence and PSS settings across the CE system will be further investigated by the concerned TSOs.
- Dynamic evaluations on system behavior are becoming more and more necessary.

It is also important to note that prompt coordination between the TSOs played a vital role in the mitigation of the transient.

Next steps



RTE is actually working with WSU to implement:

- real time analysis of oscillations, ambient and ringdown
- Generation of alarms to the control room that takes into account the mode shape => depending of the mode shape the actions would be different