

# SuperGrid Institute

# HVDC links control to enhance stability and security of power systems

### Dr. Abdelkrim BENCHAIB, R&D Expert Manager

Power transmission in Asia - Dec. 08, 2020





# SuperGrid Institute

In a nutshell







SuperGrid Institute, an independent research & innovation center developing key technologies for future electricity grids



# SuperGrid Institute

- Independent Research & Innovation centre
- Academic & industrial experts and testing facilities all in one place
- Supported by the French State and with academic & industrial shareholders



### Key figures:

- Created in 2014, located at Villeurbanne (Lyon), France
- Around 200 team members, mainly applied research staff
- More than 10 simulation & testing facilities
- More than 63 patent applications & 120 publications
- Active member of major scientific leadership groups: CIGRE, IEC, IEEE...



SuperGrid Institute, an independent research & innovation center developing key technologies for future electricity grids

# 01 Upgrading electrical grids

Reinforcing the existing transmission system and interconnecting networks to enable the transmission of a huge quantity of power over long distances  $\rightarrow$  DC technologies & systems, and integration within AC grids

# 02 Integrating renewables

Connecting renewable energy sources while managing their impact on the electrical network (decreasing inertia and intermittence)





SuperGrid Institute, an independent research & innovation center developing key technologies for future electricity grids





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Expected evolution of HVDC grids



New insulating materials





SuperGrid Institute, an independent research & innovation center developing key technologies for future electricity grids

SuperGrid Institute: An independent research and innovation centre covering the full technological chain shaping the grids of the Future



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SuperGrid Institute, an independent research & innovation center providing HVDC & MVDC innovations and services to our clients

### SuperGrid Institute's value proposition to our clients



#### SuperGrid Institute value propositions





SuperGrid Institute, an independent research & innovation center providing HVDC & MVDC innovations and services to our clients

### Come to us and we will set up together the most efficient way to collaborate, such as:

- Joint R&D long-term collaboration
- Short-term specific R&D joint collaboration
- Licensing and/or joint maturation of <u>SuperGrid Institute innovations portfolio</u>
- External collaborative research project (EU funding, etc.)
- Services subcontracted to SuperGrid Institute:
  - Subcontracted R&D
  - Testing at SuperGrid Institute facilities
  - Access to expertise through technical consulting services
  - Grid studies

For any inquiry, please feel free to contact us directly or through our website :

www.supergrid-institute.com



# SuperGrid Institute

# HVDC links control to enhance stability and security of power systems





What evolution for transmission grid?

- Wind energy is the technology expected to provide the largest contribution to the EU renewable energy targets for 2020 and beyond.
- The EU currently has the largest floating wind energy capacity in the world about 70% of the total.
- By end 2020, the total installed wind energy capacity could reach 210GW, equivalent to supplying 14% of electricity demand.
- By 2030 it could reach 350GW, supplying up to 24% of electricity demand.
  https://ec.europa.eu





# Implications of Poor FFR Location

Example Extreme Behaviour during a frequency event



Source:

Enhanced Frequency Control Capability Project Dissemination Event. Wide-Area Frequency Control Scheme Smart Frequency Control Douglas Wilson & Seán Norris 25/02/2016 http://docplayer.net/98563887-Enhanced-frequency-control-capabilityproject-dissemination-event.html





Wind Energy flow in Germany

### **Energy transition - supply security**

2015: Redispatch in high wind (1)

#### Germany's energy future....

- Long distances between generation and use
- Power transmission up to 800 km
- European internal electricity market and trading
- Large volume of fluctuating renewable generation
- ... is already here!







### HVDC links in Europe, Existing and planned



Partners for ULTRANET converters: Amprion GmbH / TransnetBW GmbH / Siemens AG



# Context of embedded HVDC links – Transient stability highlight

Potential of HVDC grids for rotor angle stability improvement

**Transient stability :** The ability of the power system to maintain synchronism when subjected to a severe disturbance, such as a short circuit on a transmission line





# **Conclusions Part 1**

Bulk power transmission impact on AC transient stability

Transient stability is one limiting factor of bulk power transmission over long AC lines.

**HVDC** transmission is a suitable solution for the AC grid reinforcement.

HVDC can help to unload AC lines, however it does not intrinsically enhance transient stability: control actions are needed.



# Supplementary controller for HVDC links

Dynamic Virtual Admittance Control – Derivation using feedback linearization

Analysis of the control law: Three main actions

$$\Delta P_{hvdc} = k_{\delta}(\delta_i - \delta_j) + k_{\omega}(\omega_i - \omega_j) + \text{Feedforward action}$$

- → Term 1: Synchronizing power (spring)
  - Power modulation in phase with power angle difference
- → Term 2: Damping power (damper)
  - Power modulation in phase with speed deviation
- → Term 3: Cancellation of nonlinearities and feedforward
  - Immediate compensation of the disturbances of the system (profit VSC fast response) – (different ways to perform this action)

[1] J. C. Gonzalez-Torres, V. Costan, G. Damm, A. Benchaib, and F. Lamnabhi-Lagarrigue, "Transient stability of power systems with embedded VSC-HVDC links: Stability margins analysis and Control." IET Generation, Transmission & Distribution (2020)



### Limitations of the concept use:

- Need of representative model of the AC system
- Identification of weakly damped modes
- Availability of measurements: Angle, speed, powers...
- Observability (measurements)/controllability of the system (topological situation of the HVDC) 16



# Dynamic Virtual Admittance (DVAC) control scheme

General concept



Using the DVAC, the power references are modulated with the objectives of:

- Transient stability enhancement
- Power Oscillations Damping
- Fast compensation of power disturbances
- Automatic modification of operating point after contingencies
- Synchronization in case of AC system trip
- Coordinated sharing of frequency reserves



### EMT simulation results

Modified Kundur's two-area system

- Kundur's modified system with embedded bipolar HVDC link
  - Extra 550 MW generation in zone 2
  - Extra 200MW installed renewables
- EMT detailed simulations including Phasor Measurement Units models





# EMT simulation results

Contingency 1 – Three phase fault



200ms three phase fault and line tripping

### **Compared control structures**

- CR → Constant References
- POD  $\rightarrow \Delta P_{hvdc} = k(\omega_1 \omega_2)$  Measurements at PCC [Latorre & Ghandari 2010]
- DVAC → Proposed control





# EMT simulation results

Contingency 2 – Uncoordinated fast frequency response



Fast frequency response: power injection

Contingency:

- Under frequency scenario
- Loss of generator 5
- Activation of the FFR
- Angular distances increase to share the reserves



# Use case: REE (Spain) – Grid2030 project

Coordinated sharing of frequency reserves



No FFR  $\rightarrow$  Stable in angular difference, but large frequency deviations

Area 1 - No Fast FCR	Area 1 - Fast FCR
——— Area 2 - No Fast FCR	Area 2 - Fast FCR





# Use case: REE (Spain) – Grid2030 project

Coordinated sharing of frequency reserves



No FCR  $\rightarrow$  Stable in angular difference, but large frequency deviations

With FCR  $\rightarrow$  First swing transient stability is lost

www.ree.es/es/sostenibilidad/anticipacion-y-accion-para-el-cambio/programa-grid2C

Area 1 - No Fast FCR	Area 1 - Fast FCR
Area 2 - No Fast FCR	Area 2 - Fast FCR





# Use case: REE (Spain) – Grid2030 project

Coordinated sharing of frequency reserves



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# Oscillations in Continental Europe : December 2016

### **Incident description**

- France imported 2250 MW from Spain
- 11h18Line 400 kV line Argia-Cantegrit tripped
- Undamped oscillations at 0.15 Hz appeared
- Corrective action
- Exchange from scheduled 2.250 MW to 1.000 MW
- 11h21: Oscillations start to be damped.



Source: Grid2030 RITSE Project



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### Investigated in RITSE Grid2030 project with REE (Spain)





Source: Grid2030 RITSE Project

https://www.ree.es/en/sustainability/anticipating-change-and-taking-action/grid2030-programme



# **Conclusions Part 2**

HVDC links with constant references do not contribute to transient stability as an AC line can do.

### Using the DVAC , embedded HVDC link contributes to:

- Increase transient stability margins
- Damp power oscillations
- Synchronize power systems even if there is no AC link
- Allow fast reallocation of the power distribution
- Power must be available in the converters to enhance stability margins
- Small signal stability AND transient stability are two separate problems. HVDC can provide solutions for both of them
- Those concepts have been extended to multi-terminal DC grids



### References

[1] J. C. Gonzalez-Torres, V. Costan, G. Damm, A. Benchaib, and F. Lamnabhi-Lagarrigue, "Transient stability of power systems with embedded VSC-HVDC links: Stability margins analysis and Control." IET Generation, Transmission & Distribution (2020).

[2] J. C. Gonzalez-Torres, V. Costan, G. Damm, A. Benchaib, F. Lamnabhi-Lagarrigue and B. Luscan, *"Procède de commande d'un lien de transmission électrique incluant une ligne haute tension continu,"* (French patent), 2018. WO2019174999A1

[3] L. Coronado, C. Longas, R. Rivas, S. Sanz, J. Bola, P. Junco, and G. Perez. *"INELFE: main description and operational experience over three years in service,"* in 2019 AEIT HVDC International Conference (AEIT HVDC), 2019, pp. 1–6.

[4] J. C. Gonzalez-Torres, V. Costan, G. Damm, A. Benchaib, and F. Lamnabhi-Lagarrigue, "A novel distributed supplementary control of Multi-Terminal VSC-HVDC grids for rotor angle stability enhancement of AC/DC systems," ,IEEE Transactions on Power Systems, 2020.





# Thank you for listening

Any questions?



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