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# Transient Stability Enhancement through the control of embedded HVDC transmission systems. Grid2030 RITSE project

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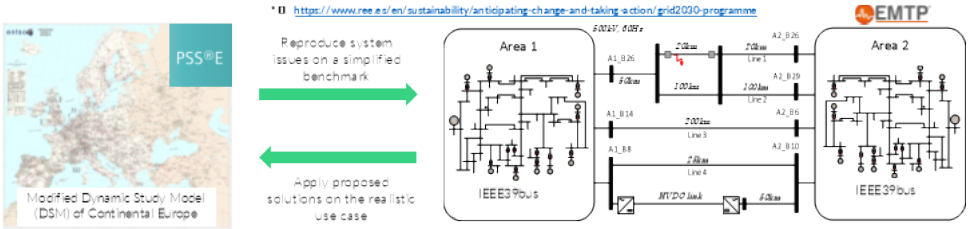
## Motivation

- The necessity to reinforce the electric transmission system is evident, and **HVDC** technology has proven to be a key element to achieve such upgrading in a secure manner
- ENTSO-E recognizes that HVDC systems must be used for more than power transmission purposes, i.e., to provide services or **"advanced functionalities"**
- Our aim: To **propose** supplementary controllers via which the embedded HVDC links can **enhance the electro-mechanical stability of the surrounding AC grid.** To test the proposed controllers on the INELFE HVDC link in simulation using a modified version of the ENTSO-E Initial Dynamic Model. Validate the control implementability in relevant industrial configurations (hardware-in-the-loop environment).

## The Reduced Inertia Transient Stability (RITSE) Project

- Collaborating with the transmission industry to reproduce their challenges and propose solutions

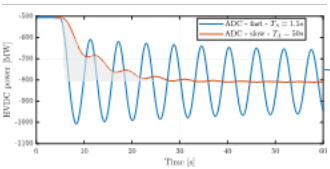

* https://www.ree.es/en/sustainability/anticipating-change-and-taking-action/grid2030-programme



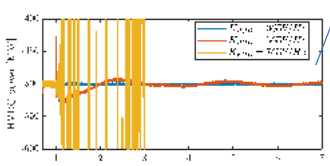

- Provide a generic solutions (Not only applicable to the FR-SP interconnection)
- Reduce the complexity of the system so component detail can be augmented (from RMS to EMT simulations)
- Avoid confidentiality issues on TSOs grid data

## Project objective

- To propose solutions of HVDC supplementary controllers for enhancing the transient stability of the surrounding AC grid. The proposition must be compatible with existing supplementary controllers




A fast filter ($T_{ADC} = 1.5s$) does not contribute to improve the system damping




High control gains ($K_{POD}$) are necessary, but they can lead to instabilities.

Angle difference control

Steady state

$(\theta_{hvdc,1} - \theta_{hvdc,2})$ → $K_{ADC}$ → $\frac{1}{1+\tau_{ADC}s}$ Low-pass filter → $\Delta P_{ADC}$

Power oscillation damping

Damping

$(\dot{\theta}_{hvdc,1} - \dot{\theta}_{hvdc,2})$ → $K_{POD}$ → $\frac{1}{1}\frac{s}{\tau_{PODs}}$ Low-pass filter → $\Delta P_{POD}$

$\Sigma$ → $\Delta P_{HVDC}$ → HVDC link

**Transient stability action**

SuperGrid institute and Red Electrica have worked together to:

- **Propose an action to exploit the fast response of the HVDC links**
- **To validate in simulation the control on the INELFE** HVDC for the European network

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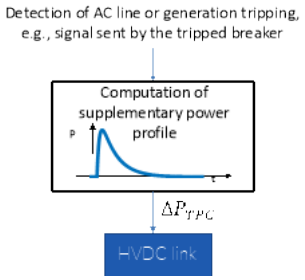
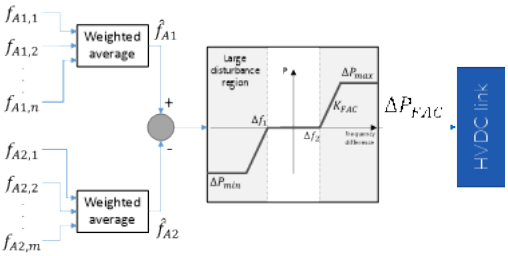
## Proposed actions for transient stability

- Triggered power compensation




- Reallocates the power of the lost line or generator on the HVDC faster than the ADC
- It converges to zero, so the steady state value of $P\_(hvdc \_ref)$ is determined by the ADC

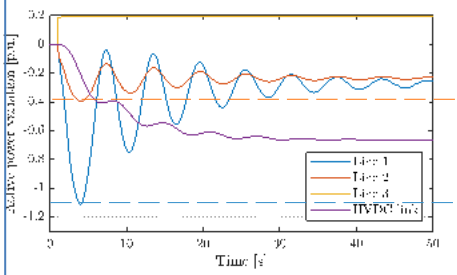
- Frequency-Activated Action (FAC)




- In case the triggered power compensation is not applicable, FAC still enables fast response
- A dead-band allows to use frequency measurements of remote buses and make sure that the modulated power is always in the right direction.

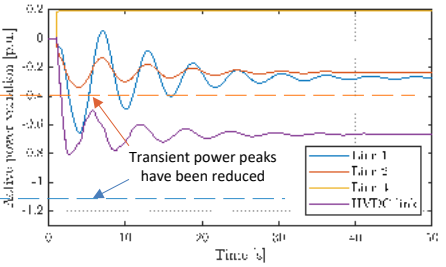
## Results on the ENTSO-E Initial Dynamic Model on PSSE

- Base case: : Only ADC with slow pass-low filter



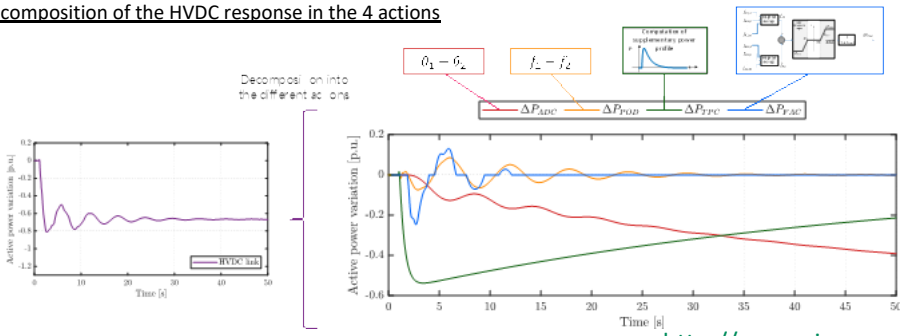

- The fast power control of the HVDC is not fully exploited to participate in the transient stability enhancement

- DVAC = The 4 actions are implemented (ADC, POD, TPC, FAC)




- The HVDC link reacts faster after the disturbance
- **Transient power peaks in parallel AC lines are reduced**, thus the risk of a cascading failure.

- Decomposition of the HVDC response in the 4 actions



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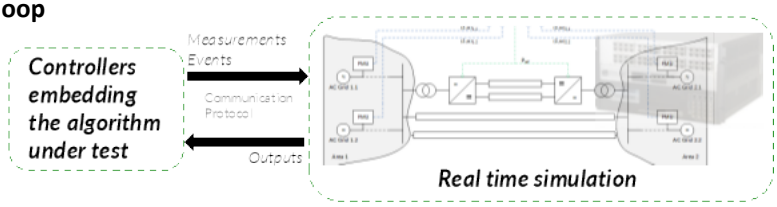
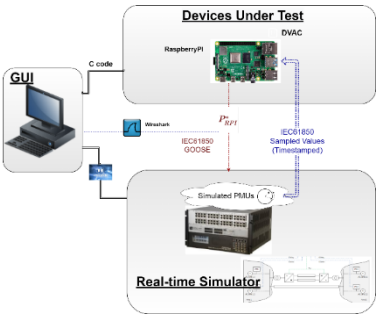
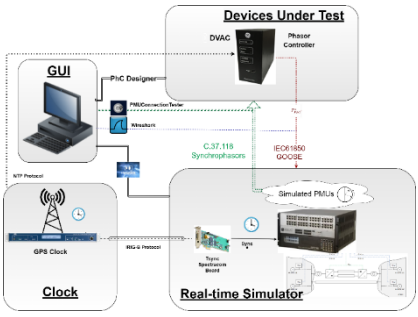
## Hardware in the loop implementation




- Setup 1: HIL validation using a **prototype controller**:

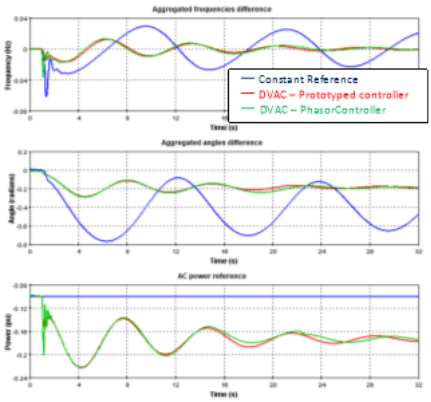



- Setup 2: HIL validation using **an industrial controller:**



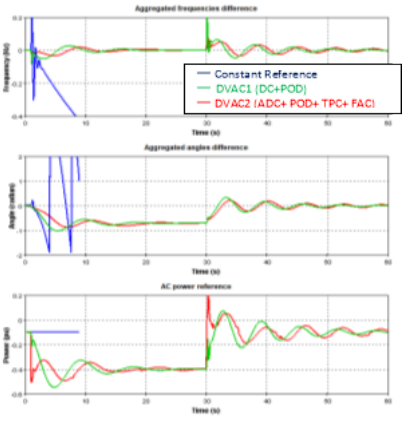

## Results

- Simulated event: Three-phase fault on one AC line cleared by line tripping .




- Both setups allow to obtain very similar results.
- Stability is enhanced when using DVAC

- Simulated event: Tripping of the two AC lines (whole AC interconnection)




- DVAC can assure synchronization of regions even if all parallel AC lines are out of service

## Conclusion

- This paper presents a complete control scheme that modulates the active power references of an embedded HVDC link to support the rotor angle stability of the system.
- Four complementary actions are combined: the Angle Difference Control (for power flow dispatch), the Power Oscillation Damping (for small-signal stability), the Triggered Power Compensation and the Frequency-difference-activated Action (both for decreasing power swings in surrounding lines).
- The benefits of the control were shown on the France-Spain interconnection, using the INELFE HVDC link in simulation of the modified ENTSO-E Initial Dynamic Model.
- The implementability of the controller on relevant industrial environments has been validated using two different setups.