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C2 PS1-3 Question 1.6: Several intelligent systems can be used in a control room. How can we guarantee that they do not compete by using different optimization and counteract each other's actions?

Introduction

Transmission systems are undergoing structural changes as the share of renewable energies accelerates. The increase of the transmission distances (renewable generation is often located far from consumption areas) and the non-uniform evolution of inertia (power plants being decommissioned, and new renewables are typically distributed non-uniformly) are two of these main changes that lead to a challenging behavior of the grid. To cope with these challenges, the transmission industry has understood that power-electronics devices (at generation, transmission, and distribution) must be used to enhance the operation of the system.

Nevertheless, it has been observed on several occasions, that controllers using power electronics devices to enhance one stability aspect can lead to issues in other stability aspects. For example, controllers aiming to redispatch an HVDC link to enhance the static situation of the grid can excite inter-area oscillations [1], grid-forming controls for enhancing the operation of weak grids come with new low frequency oscillating modes [2], etc. To guarantee that different controllers do not compete, more holistic (i.e., that consider several stability aspects) approaches for power system stability analysis and coordinated control design are necessary.

To exemplify the potential interactions between controls, in the following, an illustration on how a converter controlled to enhance the frequency stability of a system can lead to a system split due to rotor-angle transient stability (as discussed previously in [3]). Then, the role of HVDC on the transmission grid to stabilize the system is highlighted.

Example of interactions

Figure 1 shows a two-area system, with a hybrid AC/DC interconnection and with a converter in Area 1 capable of injecting fast frequency containment reserve (FCR) based on local measurements. The Fast FCR is recognized as a suitable solution for the operation of low inertia systems.

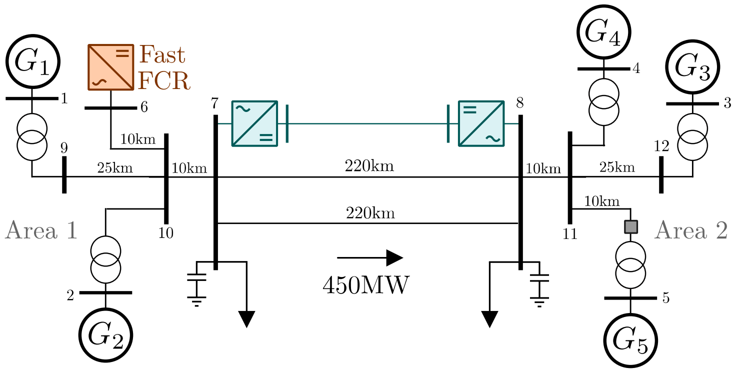

Figure 1. Test power system

The simulated event is the loss of a generator in Area 2. As shown in Figure 2, in case where no Fast FCR is deployed, about 8s after generator tripping, the primary reserves of the generators stabilize the frequency at 49.78Hz after a nadir of 49.51Hz in Area 2. The long transmission corridor is conductive to inter-area oscillations (or a non-uniform frequency response during transients).

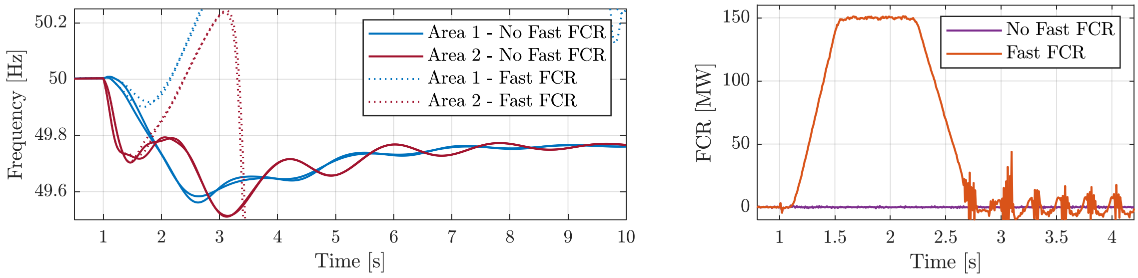

Figure 2. A) Frequency response a generator tripping. B) Fast FCR response after generator tripping.

The frequency difference during the first swing leads to an increase in the transport angle along the transmission lines, necessary to export the primary response from Area 1 to Area 2. However, if the transport angle increases beyond the stability limits, a loss of synchronism occurs. This is the case when the Fast FCR in Area 1 is deployed. In Fig. 2.B, it is observed that the Fast FCR is activated 100ms after the incident, and fully deployed 500ms after activation. The applied Fast FCR stops the frequency drop locally in Area 1 (See figure 2A, dashed line), which produces an increase of the frequency difference between areas, leading to an increase of the angle difference beyond the stability limits. The frequency event has been translated into a system split due to the Fast FCR activated in the non-affected Area.

The role of HVDC

The HVDC link in the corridor offers the possibility to enhance rotor angle transient stability thanks to its fast power control. In this example, a control called the Dynamic Virtual Admittance Control (DVAC) can be used to dynamically modify the active power references during transients by a value ΔP_{hvdc} . The control law is the following:

$$\Delta P_{hvdc} = \overbrace{k_\delta(\theta_1 - \theta_2 - \bar{\theta})}^{Synchronizing\ power} + \overbrace{k_\omega\big(\dot{\theta}_1 - \dot{\theta}_2\big)}^{Damping\ power} + \text{Disturbances compensation}$$

This control uses the measurements of angles (θ) and frequencies ($\dot{\theta}$) at the PCCs (1 and 2) to modulate the power of the links to apply synchronizing power and damping power between the two areas. A third term aims to fast compensate for power disturbances if they are measurables.

The frequency excursion when the DVAC is applied together with the Fast FCR is depicted in Fig. 3 and compared with the case without Fast FCR and constant power references in the HVDC link. The proposed control stabilizes the system by reducing the frequency difference during the first swings, thus keeping the transport angle within the stability limits. As synchronism is not lost, the Fast FCR can be properly shared and maintained (Fig. 3.B), improving the nadir and the steady-state frequency. This improvement is possible thanks to the HVDC active participation via the modulation of its power reference as seen in Fig. 4

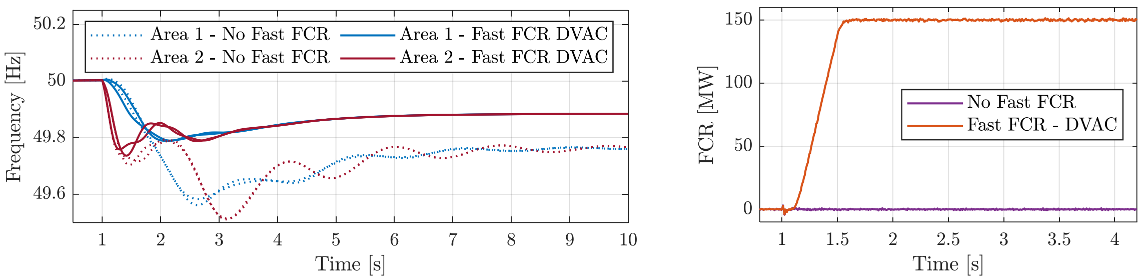

Figure 3. A) Frequency after a generator tripping. B) Fast FCR response after generator tripping.

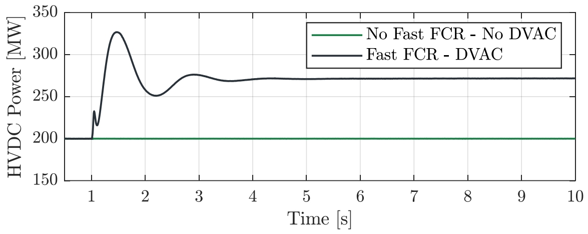

Figure 4. HVDC power after a generator tripping

Conclusion

The current evolution of the power systems comes with new challenges for operators. Actively using power electronic devices to enhance system stability seems of utmost importance to achieve a secure operation of the system. However, in evolving power systems (more volatile power systems), the controllers designed for tackling one stability aspect might enter in conflict with other stability aspects. Holistic approaches for the analysis and coordinated control design are necessary. In this contribution it has been shown that a fast FCR injected far from location of the event can lead to a transient stability problem and to the split of the system. It has been also shown that via the fast response of an embedded HVDC link, the fast FCR can be rapidly distributed along the system allowing it to remain in synchronism.

References

[1] Coronado, L., et al. "INELFE: main description and operational experience over three years in service." 2019 AEIT HVDC International Conference (AEIT HVDC). IEEE, 2019.
[2] Musca, R., et al. "Power System Oscillations with Different Prevalence of Grid-Following and Grid-Forming Converters." Energies 15.12 (2022): 4273.
[3] Luscan, B., et al. "A Vision of HVDC Key Role Toward Fault-Tolerant and Stable AC/DC Grids." IEEE Journal of Emerging and Selected Topics in Power Electronics 9.6 (2020): 7471-7485.