Interplay of inertia and damping in power grids

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Inertia and damping play a crucial role in power grid operation. In the event of a disturbance, such as a sudden change in load or the loss of a generator, the inertia from rotating masses slows down the rate of change of frequency (RoCoF), allowing time for other control mechanisms to respond. These mechanisms are responsible for damping and controlling frequency oscillations, returning the grid to a stable state.

In this work, we analyze the interplay of inertia and damping in the propagation of frequency disturbances. We run simulations using a dynamical model for the high-voltage power grid of Continental Europe [1, 2]. We examine different inertia and damping distributions, assessing the response of the system to varying fault locations. Specifically, we analyze the frequency of the grid close to the fault and at other locations within the initial seconds following the fault.

As expected, we observe that having inertia near the fault reduces the RoCoF and frequency nadir in its proximity, while damping simply reduces the amplitude of the oscillations. However, inertia also favors the propagation of inter-area oscillations, i.e., coherent oscillations recorded in distant areas. These oscillations live in the slowest modes of the network Laplacian matrix [3], which are located in the Iberian Peninsula and Balkan region in the European grid. As a consequence, in the event of a fault in the Iberian Peninsula, oscillations propagate to the Balkan region as the slowest modes are excited, and vice versa. We show that increasing damping in these specific areas, rather than homogeneously, is more effective to reduce inter-area oscillations.

[1] L. Pagnier and P. Jacquod, *PLoS One* (2019).

[2] M. Tyloo, L. Pagnier, and P. Jacquod, *Science advances* (2019).

[3] J. Fritzsch, M. Tyloo, and Ph. Jacquod, *60th IEEE Conference on Decision and Control (CDC)* (2021).