Data analysis of frequency fluctuations in the Balearic grid before and after coal closure

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In 2019, Es Murterar, the most polluting power station in the Balearic Islands, was partially closed down. Since then, the operation time of its remaining units has been heavily restricted. These measures were taken as a first step in the decarbonization agenda, and they marked the end of coal as the main electricity generation source in the territory.

The aim of this work is to evaluate the effect that the close down has in the frequency fluctuations statistics [1] which is a good proxy to monitor grid stability. We have used the open database [2], which includes 1-second measurements from October 2019 until December 2020. These were taken from a single location in Mallorca, and we assume that the frequency is the same in the other islands. Moreover, since the frequency is closely related to the demand-generation balance, we have also looked at the power data publicly available on the web site of Red Eléctrica de España (REE) [3]. In particular, they provide 10-minutes averaged data of the overall demand and generated power disaggregated by power plant technology, as well as the power through the High Voltage Direct Current (HVDC) line to the mainland.

Comparing the data from before and after the close down, we have seen that coal has been replaced by Combined Cycle Gas Turbine (CCGT). This has lead to a significant reduction of frequency fluctuations (see Figure 1), which indicates that the overall control capacity of the Balearic grid nowadays is significantly larger than before which indicates that CCGT power plants have a faster and more powerful control response than the coal plant.

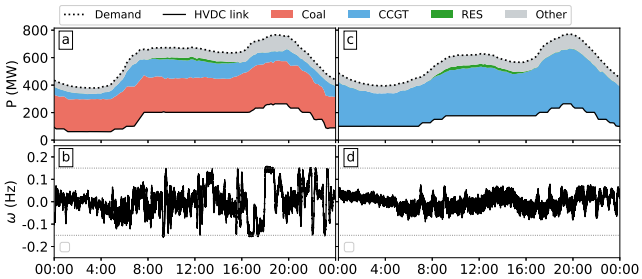

Fig. 1. Evolution of the demand and generation, and grid frequency in (a,b) a day in which coal was the main generation source compared to (c,d) a day when there was no coal generation. Generation is disaggregated by technology, including the HVDC connection to mainland. The dotted lines in the frequency plots indicate the statutory operational limits, i.e., (50.00 ± 0.15) Hz.

In order to characterize the frequency deviations, we use the rank size distribution. In Figure 2a, we show the rank of the two frequency time series from Figure 1. When CCGT is the main generation source, the shape of the curve shows a smooth decay in the probability of having large fluctuations. In other words, the frequency tends to stay close to its nominal value, and large deviations are highly unlikely. However, for the case when coal is the main generation source, we see a much slower decay of frequency deviations up to 0.15 Hz, which indicates there is a significantly larger probability, followed by a very steep drop.

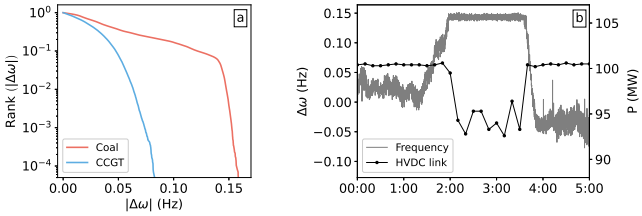

Fig. 2. (a) Rank size distribution of the absolute value of the frequency deviations for two days in which coal and CCGT were the main generation sources (Figure 1). (b) Evolution of the grid frequency and HVDC link power when frequency fluctuations reach ±0.15 Hz.

The typical frequency control mechanisms of conventional power plants act proportionally to the frequency deviation and tend to restore the frequency back to its nominal value, thus for most power grids the frequency distribution decays smoothly [4]. The existence of a threshold-like value, beyond which there is a much stronger damping of fluctuations, is a singularity in the Balearic system associated to the HVDC cable. If the frequency is within the statutory range ±0.15 Hz, the HVDC cable operates at a given set point without providing control. When the frequency deviation reaches reaches the limits then the power of the cable is continusly adjusted to avoid frequency deviations beyond that limit as shown in Figure 2b.

This control mechanism was frequenly activated when the coal power plant was the main source of generation due to the larger frequency fluctuations while its activation is quite rear since generation is dominted be combined cycle. The fact that fluctuations has reduced after the closure of the coal plant (which provided substantial inertia to the system) is a clear indication that inertia reduction is not as relevant for grid stability as having a fast flexible control.

[1] M. Martínez-Barbeito, D. Gomila, and P. Colet, *Data analysis of frequency fluctuations in the Balearic grid before and after coal closure*, ENERGY 2021, pp. 13-18 (2021).

[2] `https://power-grid-frequency.org/`

[3] `https://demanda.ree.es/visiona/home`

[4] L.R. Gorjão, R. Jumar, H. Maass, V. Hagenmeyer, G.C. Yalcin, J. Kruse, M. Timme, C. Beck, D. Witthaut, and B. Schäfer, *Open database analysis of scaling and spatio- temporal properties of power grid frequencies*, Nat. Commun., vol. 11, no. 1, pp. 111 (2020).