Effects of high penetration of wind power in the frequency fluctuations of Gran Canaria's power grid

María Martínez-Barbeito[1], Damià Gomila[1], and Pere Colet[1]
[1]Instituto de Física Interdisciplinar y Sistemas Complejos (IFISC, UIB-CSIC), Campus Universitat de les Illes Balears E-07122 Palma de Mallorca, Spain

The need to address the effects of climate change is accelerating the transition towards a more sustainable energy system. The progressive replacement of conventional power plants by variable renewable energy sources (VRES) will reduce both the inertia and the frequency control capabilities of the system, diminishing the overall flexibility of the grid as a consequence. Thus, additional control strategies will be needed to ensure stable operation.

In this work, we address this issue by simulating a power grid with different ratios of wind power. Our approach is based on the perhaps most common in the literature [1], which is the use of the swing equation and Kuramoto-like models of synchronous motors. We propose an extended dynamical model for the high voltage power grid, which includes conventional generators with primary and secondary frequency control, operation set points, fluctuations from demand and VRES, and the grid topology [2].

The first step in our study was to calibrate the model against observations. In Figure 1.a,b, we see that the model correctly captures frequency deviations in accordance to wind power ramps. In fact, it reproduces the frequency time series and the main statistical properties with a reasonable accuracy (Figure 1.c,d). However, there are some discrepancies, which we associate to simplifying assumptions of the model and lack of faster timescale data.

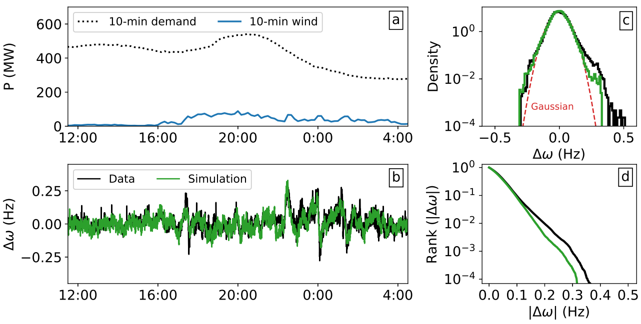

Fig. 1. (a) Evolution of demand and wind generation data [3]. (b) Time series, (c) probability density, and (d) rank size distribution of frequency fluctuations given by the model in comparison to the data [4].

After calibrating the model parameters to best fit the data, we have a model that can be used as a test bench to study the power grid under different scenarios. In this work, we focus on the effects of a high penetration of VRES. In particular, we study future scenarios with a high ratio of wind power in the Canary Islands, where wind is a major resource. We perform simulations for increasing amounts of wind in the system. Taking 2019 as our reference case, we multiply the wind generation data by a factor and we evaluate the frequency control needs.

Nowadays, wind generation covers a small fraction of the demand, and frequency deviations stay close to the statutory limits. However, increasing the wind capacity changes the size of the wind profile and magnifies wind fluctuations. In turn, frequency deviations become larger, except for the time windows where the wind generation exceeds the demand. In these cases, we only feed into the grid the demanded amount and the excess power is simply discarded. Curtailment in case of extra wind generation is another control mechanism, showing benefits to some extent.

To keep frequency fluctuations within reasonable limits, we have to increase the amount of control in the system. In our case, since we only study wind changes through the 10-minute data, we increase secondary control, which is responsible for adjusting the frequency over this timescale.

We observe that increasing secondary control reduces the size of all frequency deviations. But the key question is how much control is needed to keep fluctuations within the range 50 ± 0.2 Hz. We answer this question both by numerical simulations and by an analytical approach. As expected, the control needed to decrease fluctuations increases with wind penetration. Up to a certain point, there is a linear relationship between the secondary control gain parameter κ and the installed wind power (Figure 2). However, for bigger fractions of installed wind power, there is a plateau due to the curtailment. We obtain a good agreement between the analytical approach and the numerical simulation results for scenarios with up to 4 times the current wind capacity, but our analytical formula to estimate the needed secondary control capacity underestimates the need for secondary control for higher wind penetrations.

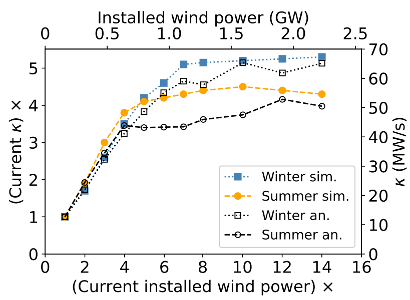

Fig. 2. Secondary control gain parameter κ needed to keep fluctuations within statutory limits as wind capacity increases.

[1] T. Nishikawa, and A.E. Motter, New J. Phys., 17(1), 015012 (2015).

[2] M. Martínez-Barbeito, D. Gomila, and P. Colet, Submitted for publication (2022).

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

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