

Dinàmica de xarxes elèctriques amb gran penetració de renovables

Damià Gomila i Pere Colet



UNIT OF
EXCELLENCE
MARÍA
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Trobada UIB – Clúster per a la Transició
Ecològica de les Illes Balears
Campus UIB, 7 d'octubre de 2022

Power networks are composed of a large number of power plants, lines, substations, ...



Generation



Transmission



Distribution



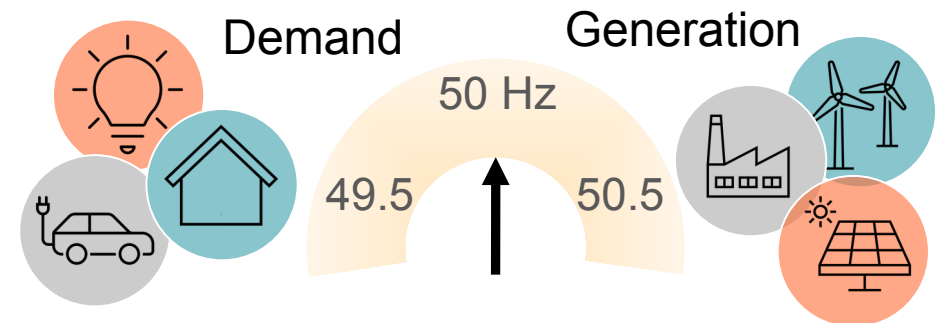
Consumption

**Practically
no storage**

Generation and demand must balance

Instantaneous unbalances translate into frequency fluctuations.

Statutory limit for continental Europe: $\pm 0.15\text{Hz}$.



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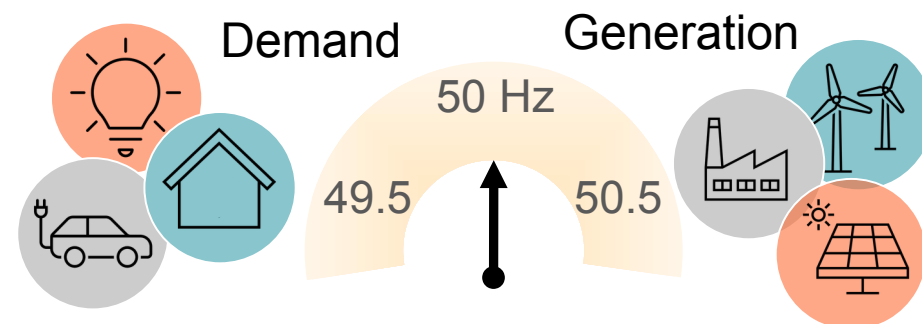
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Balance not trivial due to load variability

Traditionally generation adapts to demand. This requires:

- Extra generation capacity ready for use in power plants (spinning reserve).
- Fast response generation units that can be brought online in few min. (non-spinning reserve).



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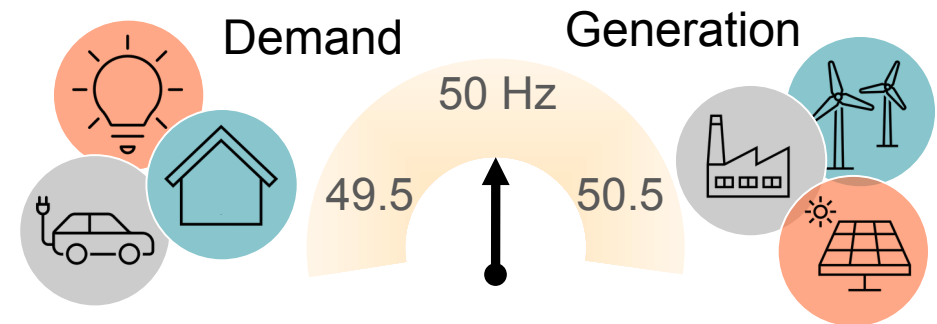
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Need to reduce CO₂ emissions:

- Increase variable renewable sources (VRES)
- Higher electrification degree.
- Additional fluctuations at generation side.
- Less control capability.
- Less inertia: more vulnerability to fluctuations.

Nodes with conventional generation

$$\dot{\theta}_i = \omega_i$$

Phase equation.

$$\dot{\omega}_i = \frac{\omega_R^2}{2 H_i P_i^G \omega} [P_i^m - P_i^e]$$

Swing equation. Inertial response

$$\dot{P}_i^m = \frac{1}{\tau} \left[P_i^s - P_i^m - \frac{P_i^G}{R \omega_R} (\omega_i - \omega_R) \right]$$

Primary control.

$$\dot{P}_i^s = -\frac{\kappa}{\omega_R} (\omega_i - \omega_R) + \lambda_i (P_i^s - P_i^{ref}(t))$$

Secondary control + forcing to a reference power (dispatch)

$$P_i^e = \left(1 + D \frac{\omega_i - \omega_R}{\omega_R} \right) P_i^l(t) + \sum_j K_{ij} \sin(\theta_i - \theta_j) - P_i^R(t)$$

Local load + transmission
+ renewable generation



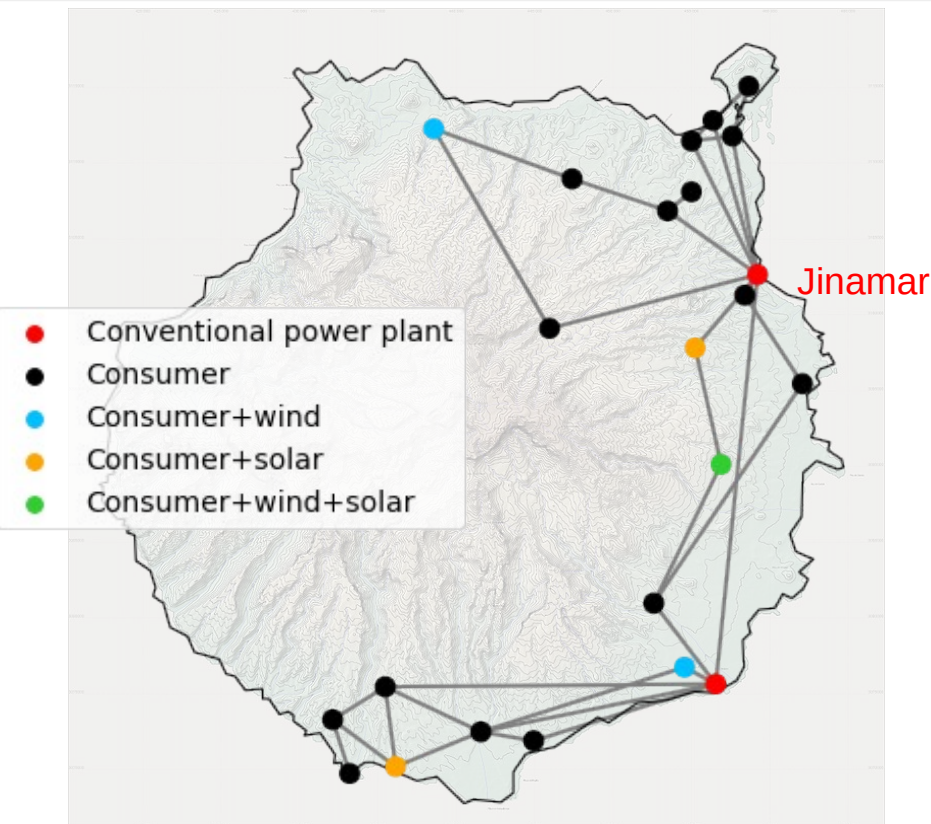
Nodes without conventional generation (may include renewables)

$$\dot{\theta}_i = \omega_i$$

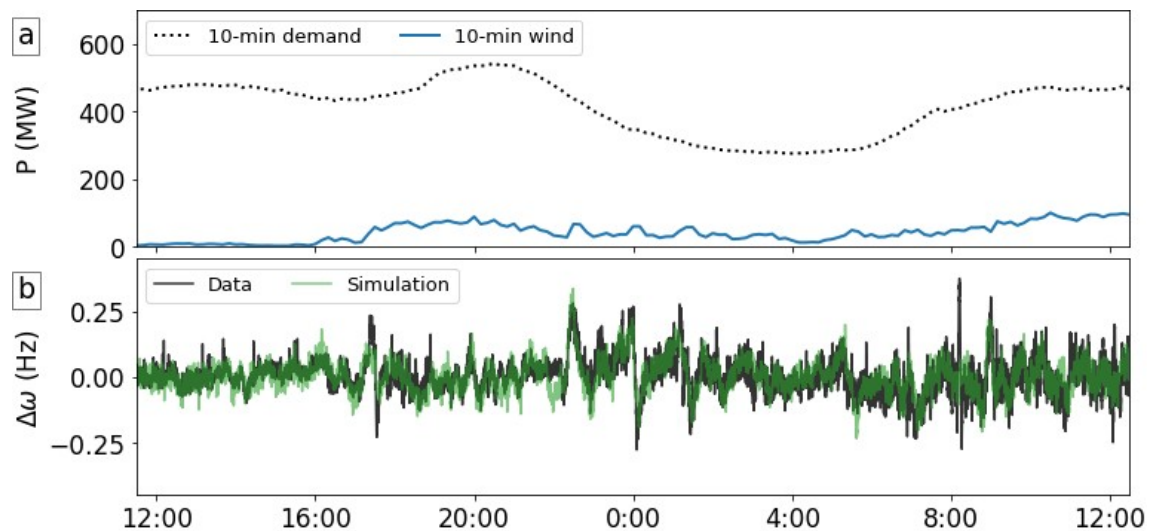
$$\dot{\omega}_i = \frac{\omega_R^2}{2 H_{eff} P_{eff}^G \omega} \left[- \left(1 + D \frac{\omega_i - \omega_R}{\omega_R} \right) P_i^l(t) - \sum_j K_{ij} \sin(\theta_i - \theta_j) + P_i^R(t) \right]$$



Data assimilation: load $P_i^l(t)$, renewable generation $P_i^R(t)$ and plant reference power $P_i^{ref}(t)$

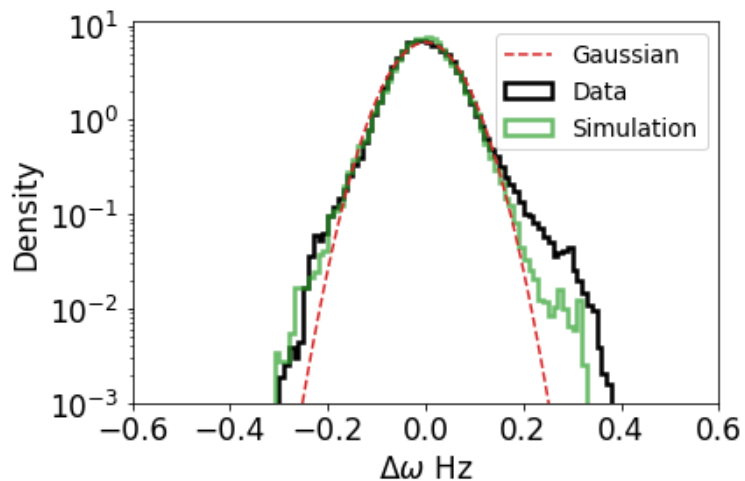


Demand & generation from
<https://demanda.ree.es/visiona/home>

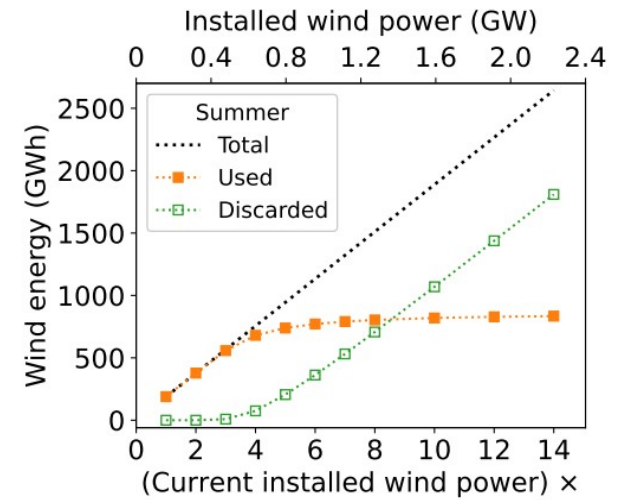
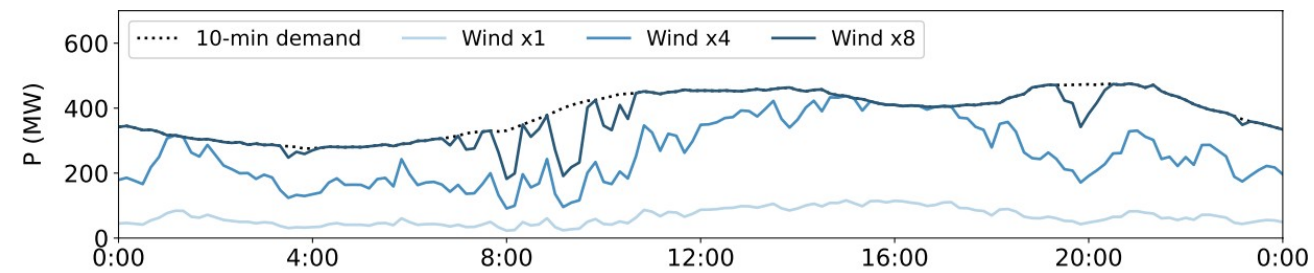


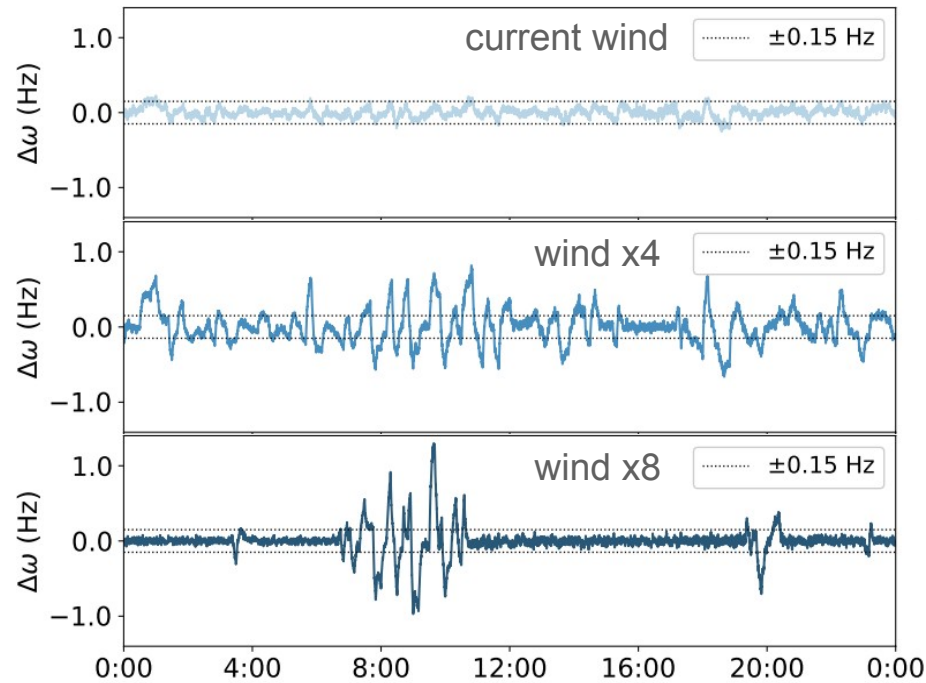
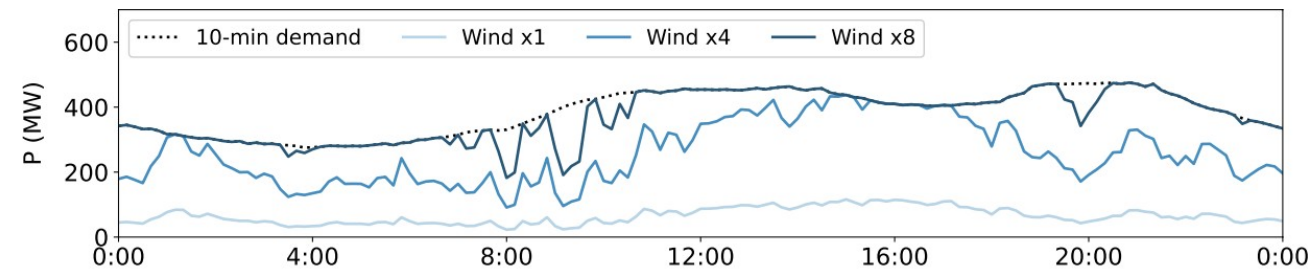
— actual freq. data, <https://power-grid-frequency.org>
 — Technical digital twin

Frequency fluctuations probability density

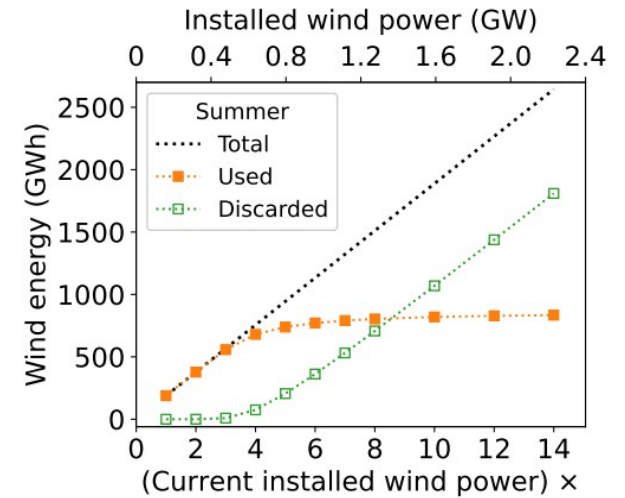


Frequency power spectrum

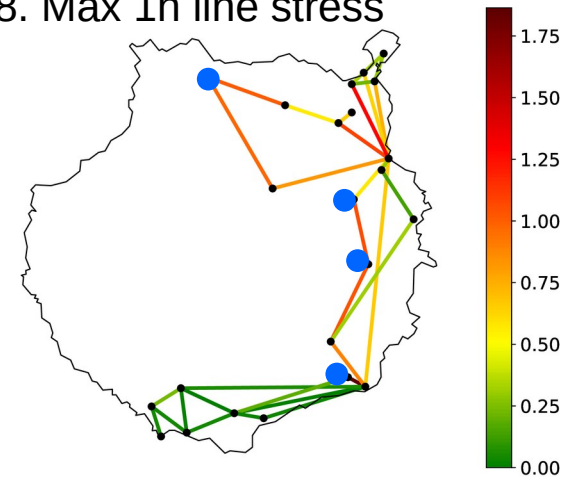


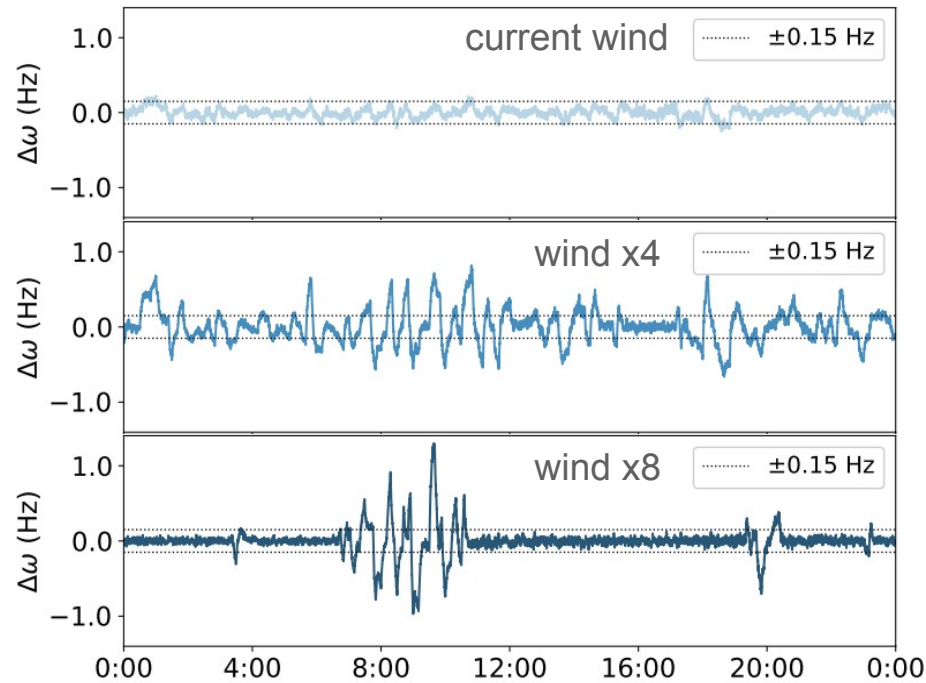
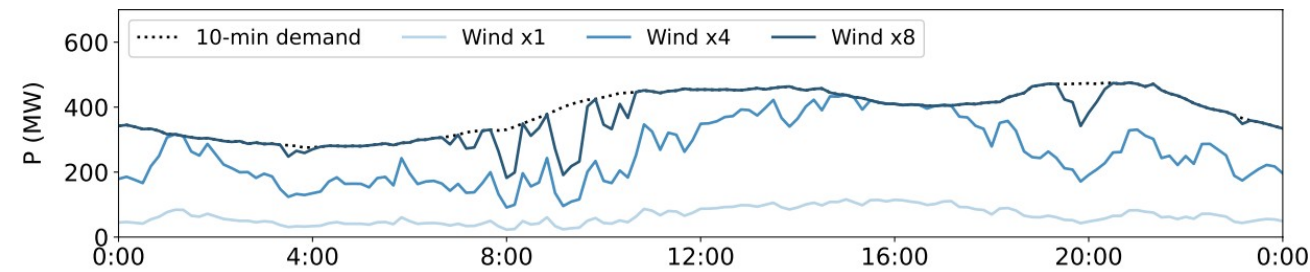


Keeping
largest power
plant with
control &
inertia even if
not needed



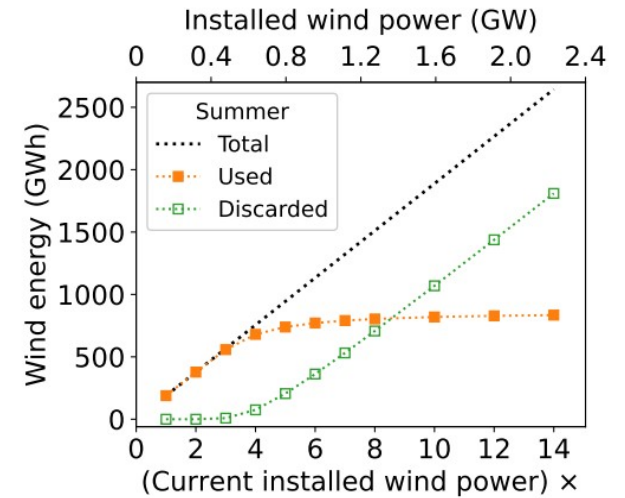
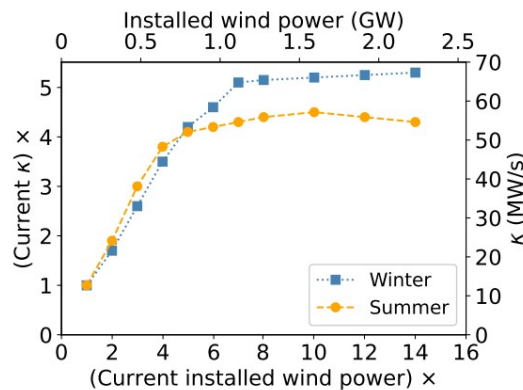
Wind x8. Max 1h line stress



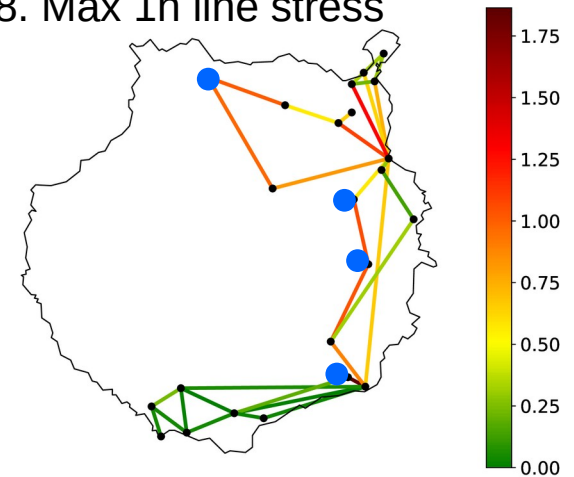


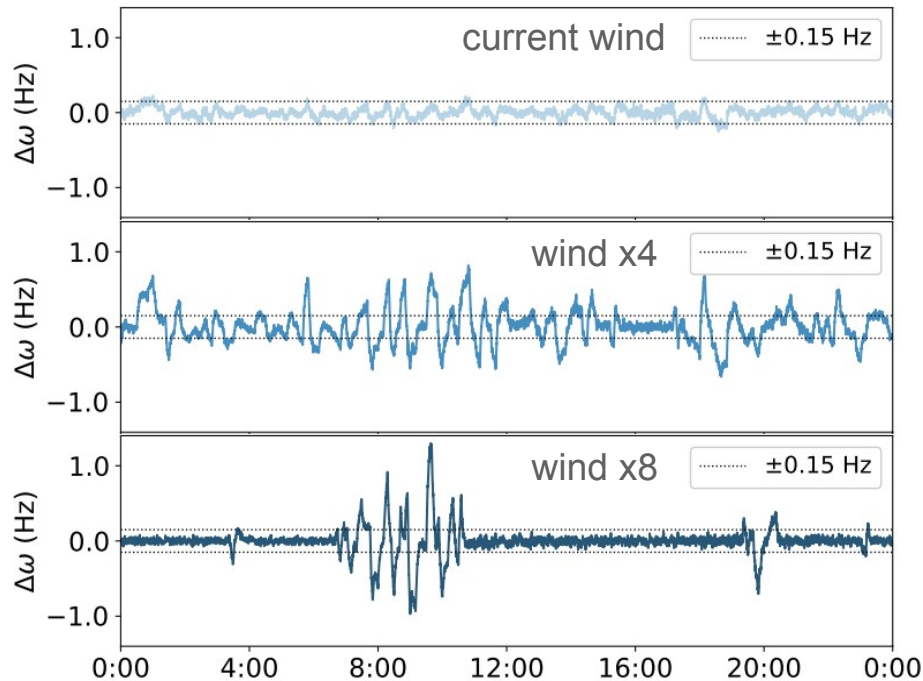
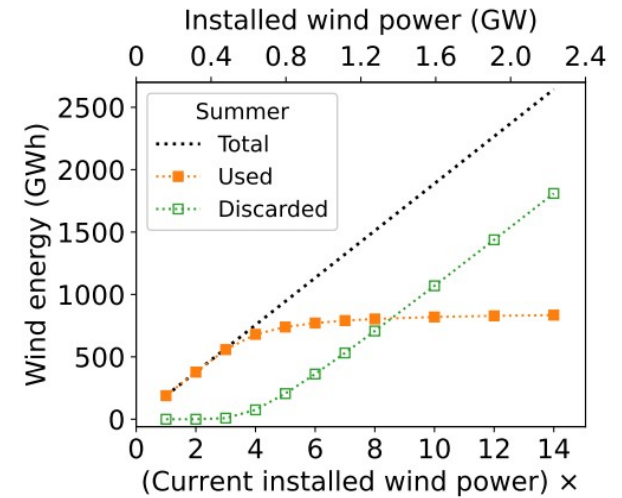
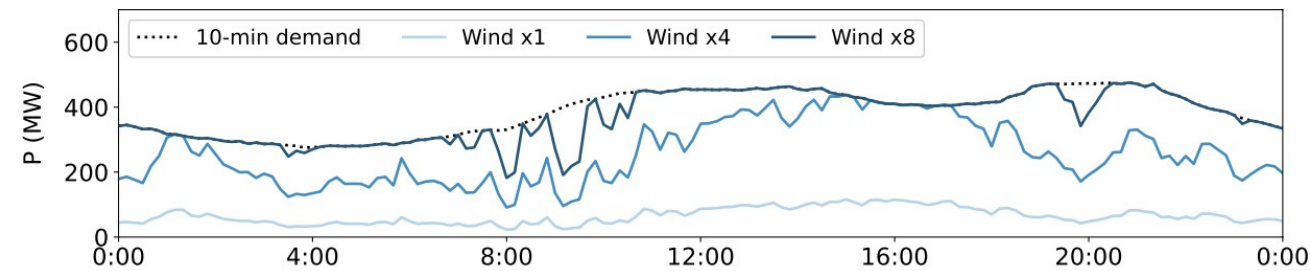
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Largest power
plant + additional
secondary control



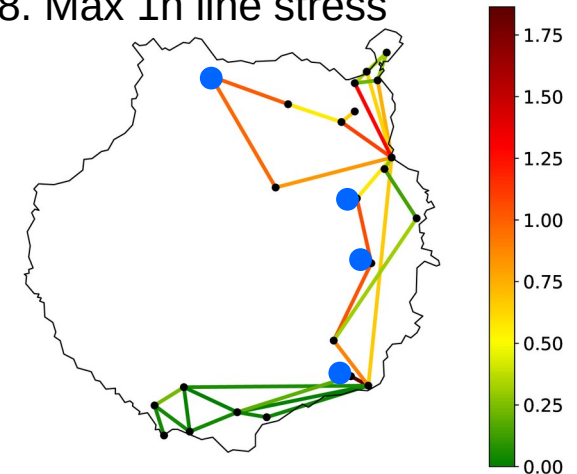
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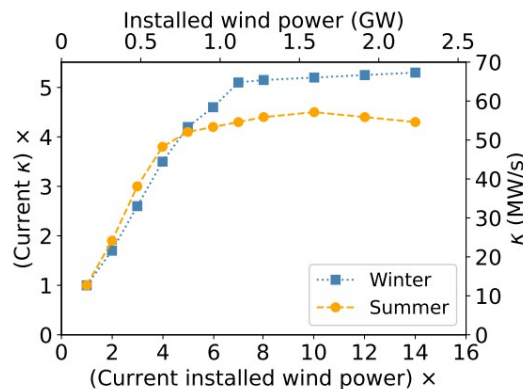


Keeping largest power plant with control & inertia even if not needed

Wind x8. Max 1h line stress



Largest power plant + additional secondary control



Balearic islands case ready.

Flexibility to explore other scenarios:

- Increasing PV generation
- Storage
- Line failures / new lines
- Different demand control techniques



El objetivo de la Unidad de Innovación **Data Analytics @ IFISC_UIB** es la transferencia de conocimiento y tecnología en los campos de *BIG DATA*, *técnicas de aprendizaje automático (Machine Learning)* e *Inteligencia Artificial* desde la Universidad de las Islas Baleares (UIB) a empresas e instituciones públicas.

La unidad ofrece sus servicios en 4 líneas principales:

- Estadística y análisis de datos. Desarrollo transversal de técnicas de Big Data, técnicas de aprendizaje automático e Inteligencia Artificial en general.
- Urbanismo, Transporte, Movilidad y Turismo.
- Energía y Sostenibilidad.
- Investigación y gestión sanitaria.

Data Analytics @ IFISC_UIB es una unidad interdisciplinar que integra a personal de varios departamentos, institutos y servicios de la **UIB** y cuenta con la infraestructura de computación, minería y almacenamiento de datos propia del **IFISC**. La Unidad cuenta con el apoyo de personal externo a la UIB y de técnicos de datos y de gestión de proyectos del **IFISC**

