Imperial College London

Towards a Cost-Effective Operation of Low-Inertia Power Systems

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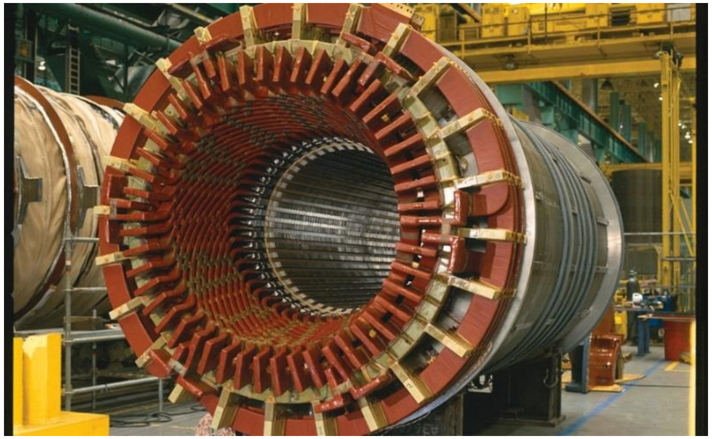
Intro: what does "low inertia" mean?

"Inertia" means physical inertia, a **rotating mass**

Thermal generators (nuclear, gas, coal…):



Most renewables: no inertia

Inertia is related to frequency:
the rotating speed of these masses is what sets the electrical frequency at 50Hz.

Why is frequency important?

Devices can be damaged if frequency falls too low: protection mechanisms disconnect generators and loads if they detect low frequencies.

Risk of frequency instability has increased due to low inertia: the kinetic energy stored in the rotating masses gave us time to contain the frequency drop!

My research: “insurance” to prevent outages

Swing equation:

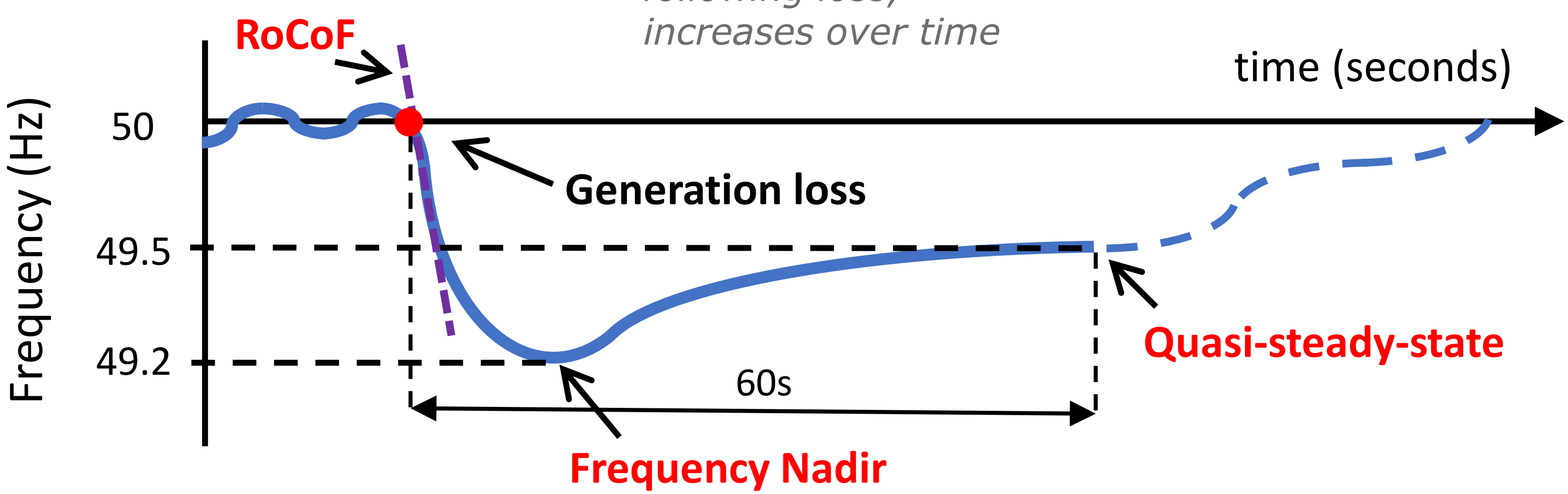
Loss of largest power infeed (N-1 requirement)

$$2H\frac{\mathrm{d}\Delta f(t)}{\mathrm{d}t} + \mathrm{D}\cdot\mathrm{P_D}\cdot\Delta f(t) = -\mathrm{P^{max}_{Loss}} + \sum \mathrm{FR}(t)$$

Power injection following loss, increases over time

Nomenclature

- H: System's inertia
- D: Load damping factor
- $\mathrm{P_D}$: System's demand
- $\mathrm{P^{max}_{Loss}}$: Largest possible power loss in the system
- $\mathrm{FR}(t)$: Frequency Response



My research in a nutshell

Goal: to optimise the cost of ancillary services that are needed because of low inertia

Described by ***differential equations***

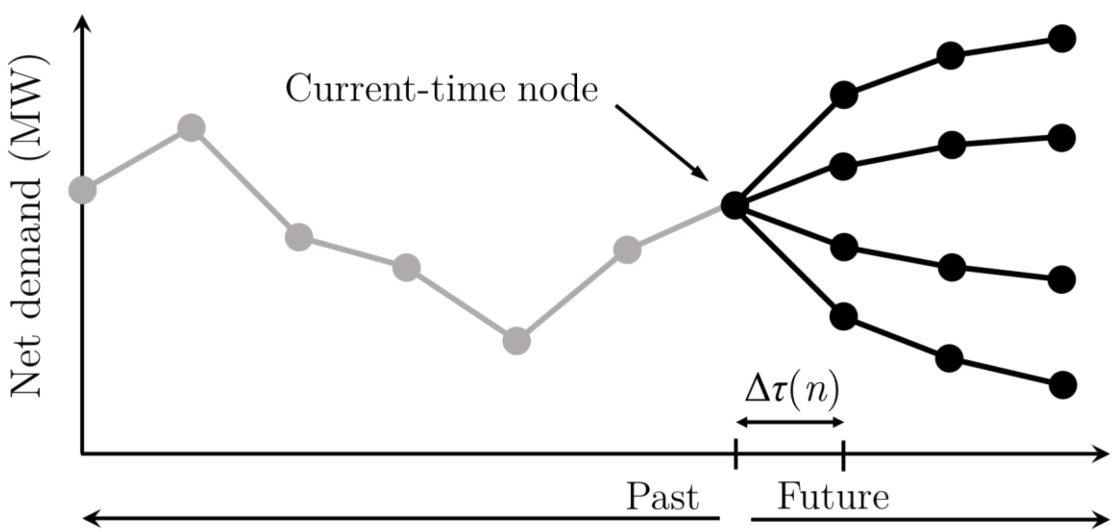
Based on ***algebraic equations***

Achieve **minimum cost** while keeping the **system stable**

Optimisation of Power System's Operation

My frequency-security constraints can be applied to:

1. Optimal Power Flow and **Unit Commitment**
   - We use Stochastic Unit Commitment, to model uncertainty from renewables



$$\min \sum_{n \in \mathcal{N}} \pi(n) \sum_{g \in \mathcal{G}} C_g(n)$$

subject to RoCoF constraint
Nadir constraint
SteadyState constraint

(and other typical constraints)

Relevance of my research

Applied to a **current power system**:

- Allows to optimally operate the system, for example dynamically reducing the largest power infeed. Particularly valuable for systems with high renewable penetration.

Applied to **potential future scenarios** of generation mix or market structure:

- Allows to study the value of different technologies (fast power injections from battery storage, flexibility from thermal units, etc.).

Want to know more?

Want to know more on **optimising the provision of this "insurance"**?

- Check my website https://badber.github.io/

  Topics like Stochastic Programming, Convex Optimisation,

  Chance constraints…

Don't hesitate to contact me too! luis.badesa@gmail.com