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

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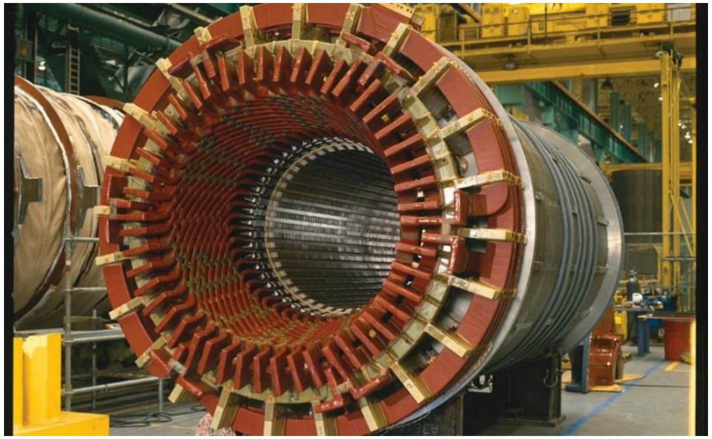
What does "low inertia" mean?

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

Thermal generators (nuclear, gas, coal…):



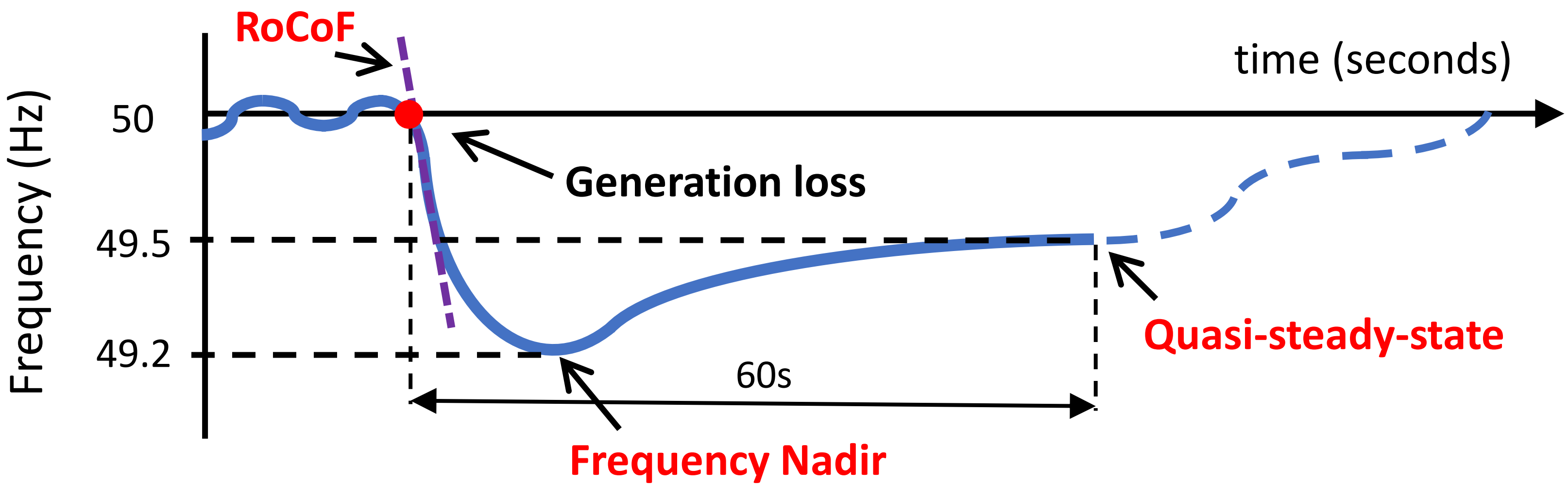
Most renewables: no inertia

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

Motivation of this research:

lower inertia on the road to lower emissions

Why is frequency important?



After a generation outage, the electric frequency of the grid drops.

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

These disconnections, although necessary, **could lead to an eventual blackout**.

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 in a nutshell

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

Described by ***differential equations***

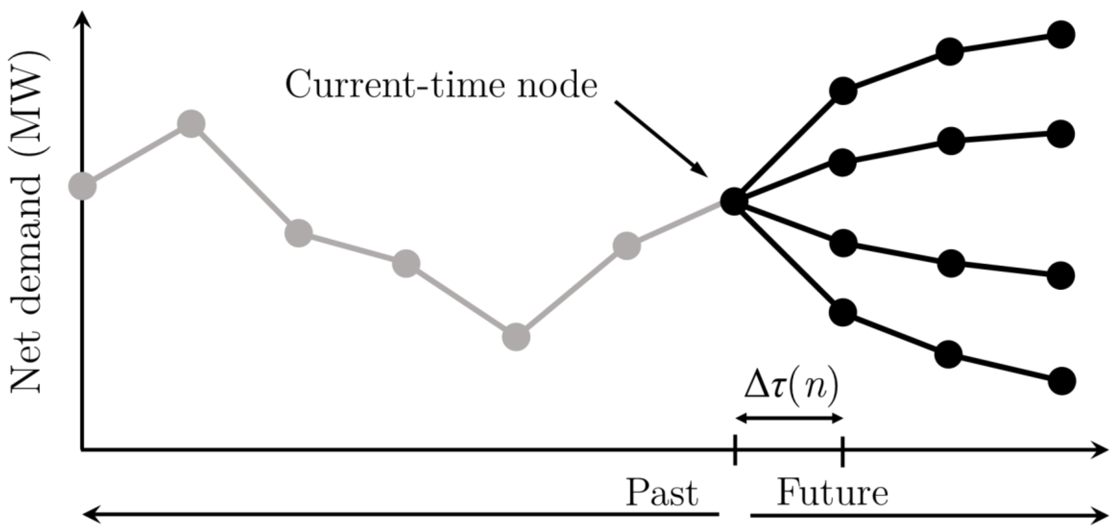
Based on ***algebraic equations***

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

Optimisation of Power System's Operation

We develop frequency-stability constraints that can be applied to optimisation problems:

We use **Stochastic Unit Commitment**, to model uncertainty from renewables



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

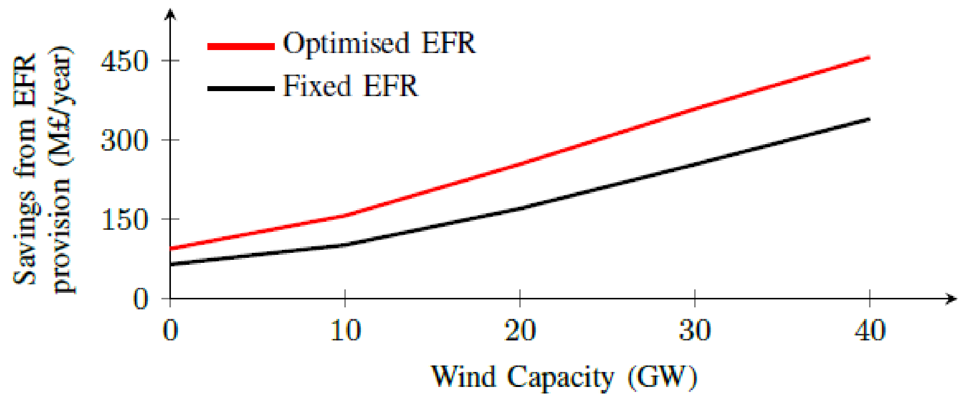
subject to RoCoF constraint
Nadir constraint
SteadyState constraint

(and other typical constraints)

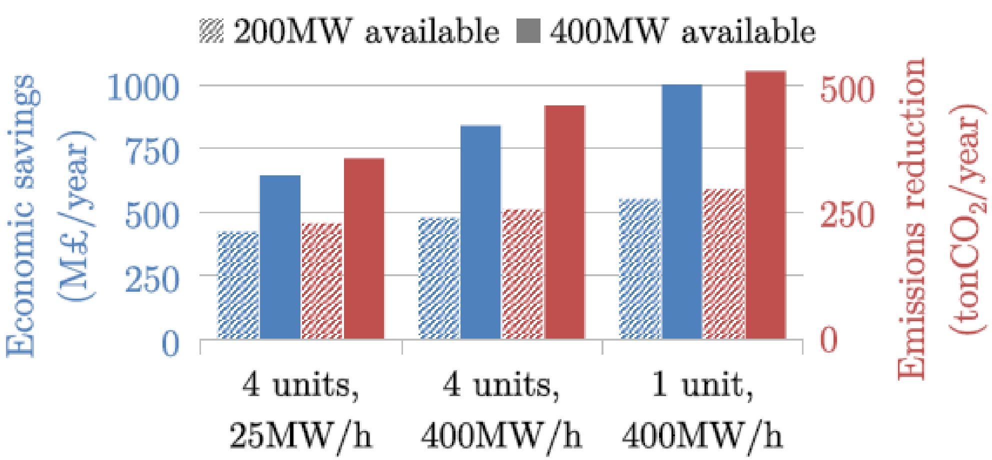
Co-optimisation of multiple frequency services

Two examples of the advantages of our models:

- **Savings of hundreds of millions of pounds per year** from optimising Enhanced Frequency Response, as compared to National Grid's current fixed volume



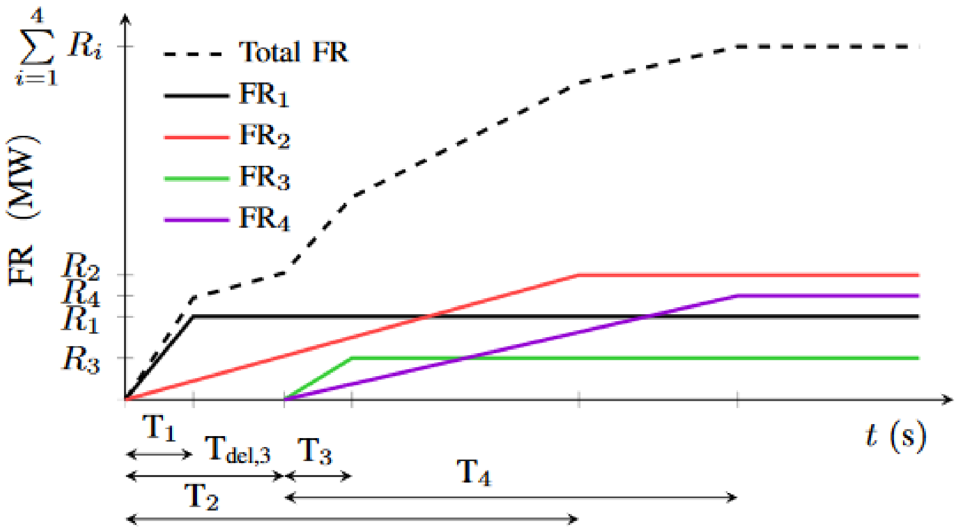
- **Significant reduction in carbon emissions** from optimally part-loading nuclear units



More info here

Marginal-pricing mechanism for frequency services

We have developed a pricing scheme that allows to consider any combination of different frequency-response dynamics and activation delays:



This formulation allows to **fully extract the value of the different assets** in a power system, **putting in place the right incentives** for those assets to provide the fastest frequency response possible.

More info here and here

Relevance of this 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.).

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Want to know more?

Want to know more about **this “insurance” to prevent blackouts**?

- 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