How to design economic mechanisms for efficient operation of low-inertia power grids

TRANSIT

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3 topics covered

1. **Unlocking the support from DER** via risk-constrained optimization

2. From **low-level control** instructions to **system-level optimization** via data-driven methods

3. **Who should pay** for frequency-containment services?

Paper:

C. Matamala, L. Badesa et al., “Cost Allocation for Inertia and Frequency Response Ancillary Services,” ***IEEE Trans. on Energy Markets***, 2024

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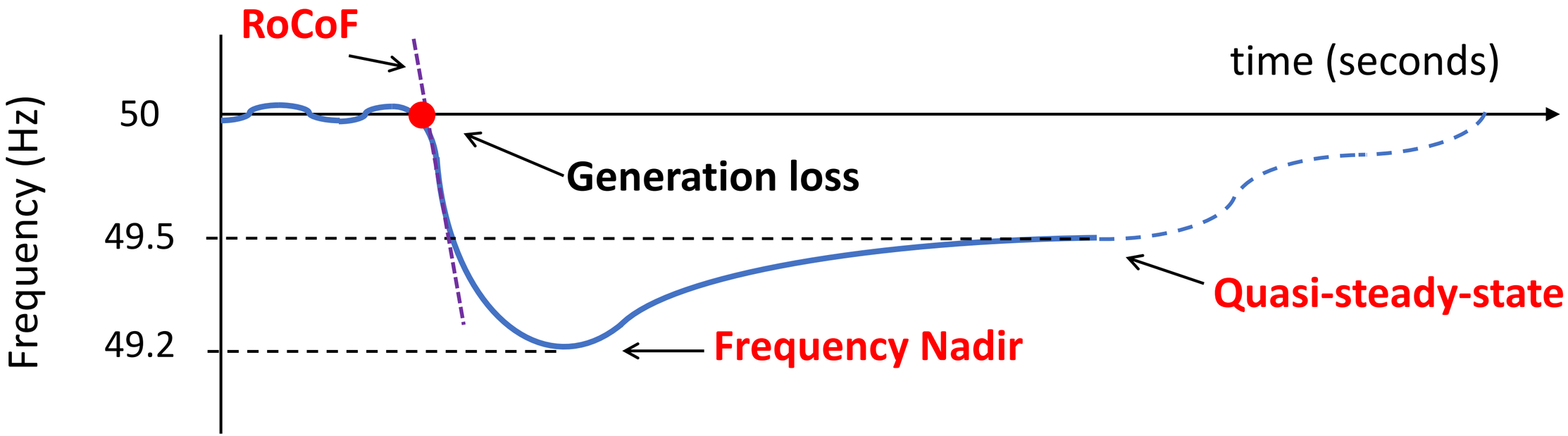
Frequency stability



Key to keep frequency within safe limits to **avoid demand disconnection!**

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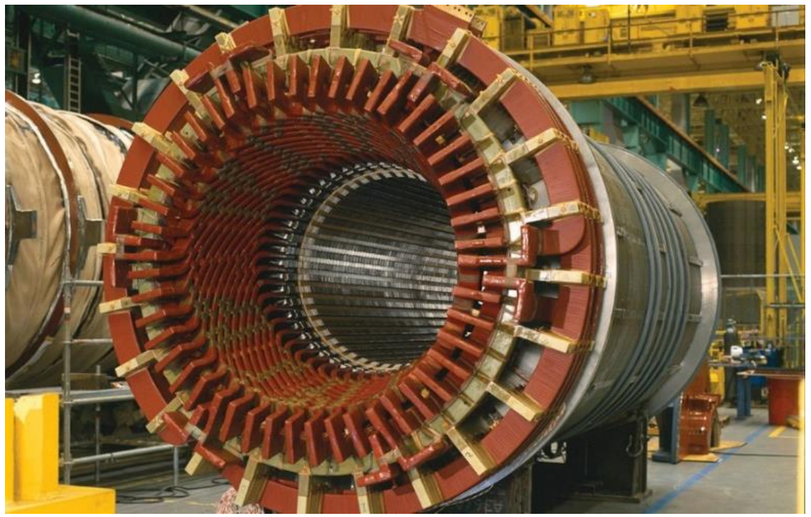
Lower inertia on the road to lower emissions

Thermal generators (nuclear, gas, coal…):



Decarbonization

Most renewables: ***no inertia***

The **risk of instability has increased!**

Inertia <u>stores kinetic energy</u>:

this energy gave us time to contain a sudden generation-demand imbalance

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Cost allocation for frequency services

We have focused on optimizing the total cost of frequency services, but…

1. **Who should cover this cost?**
   - Generators?
   - Consumers?
   - Only a subset of the former?

2. **How much should each market participant pay?**

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First, why worry about who pays?

- Currently **costs are socialized** in most countries (except Australia)
- **Until recently**, irrelevant who paid (**costs were small** due to high inertia)

Goal of moving towards a **'causer pays' framework**:

To create **incentives to 'do less harm'** to the grid

(in order to **reduce the cost** of frequency services for consumers)

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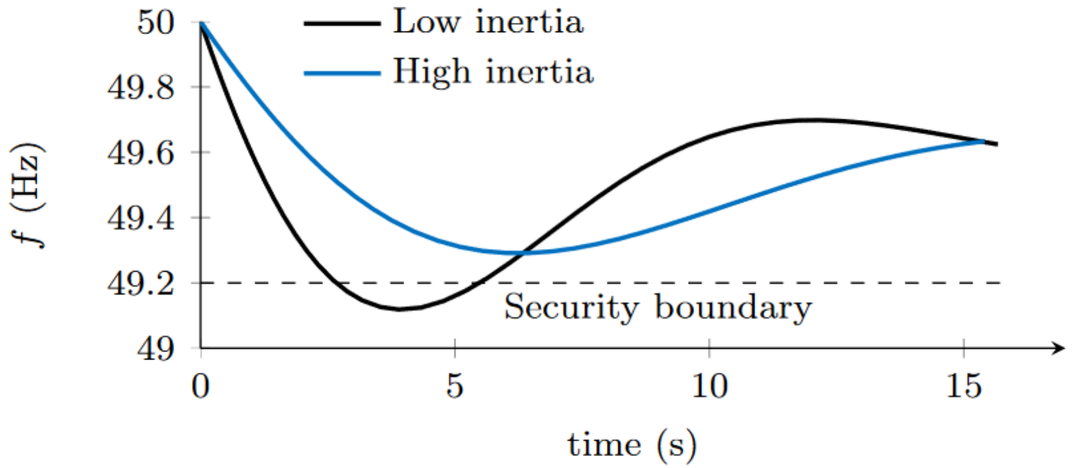
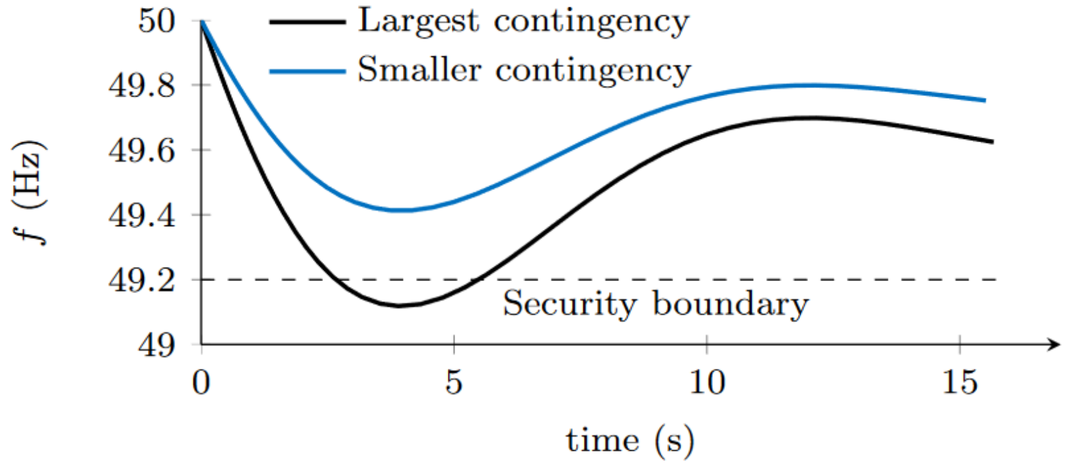
Who causes the need for frequency services?

Large units do: a low-inertia system would do fine if all units were small (there would be no large, sudden power imbalances)



Impact of inertia

under a large contingency



Impact of contingency size

in a low-inertia system

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Who causes the need for frequency services?

Large units do: a low-inertia system would do fine if all units were small (there would be no large, sudden power imbalances)

We **rule out penalizing** the **lack of inertia**

- Inertia is a service, it should be remunerated appropriately
- But lack of inertia is not a problem by itself

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How to split the cost?

Option 1: **proportional cost allocation**

- ✓ Easy to design: **each unit pays in proportion to its size**
- ✓ Creates **incentive** for large units **to ‘do less harm’**
- **Problem**: it **maintains cross-subisidies**

  (small units still subsidize large ones)

Option 2: **sequential cost allocation** (coming next)

- ✓ Advantage: no cross-subsidies

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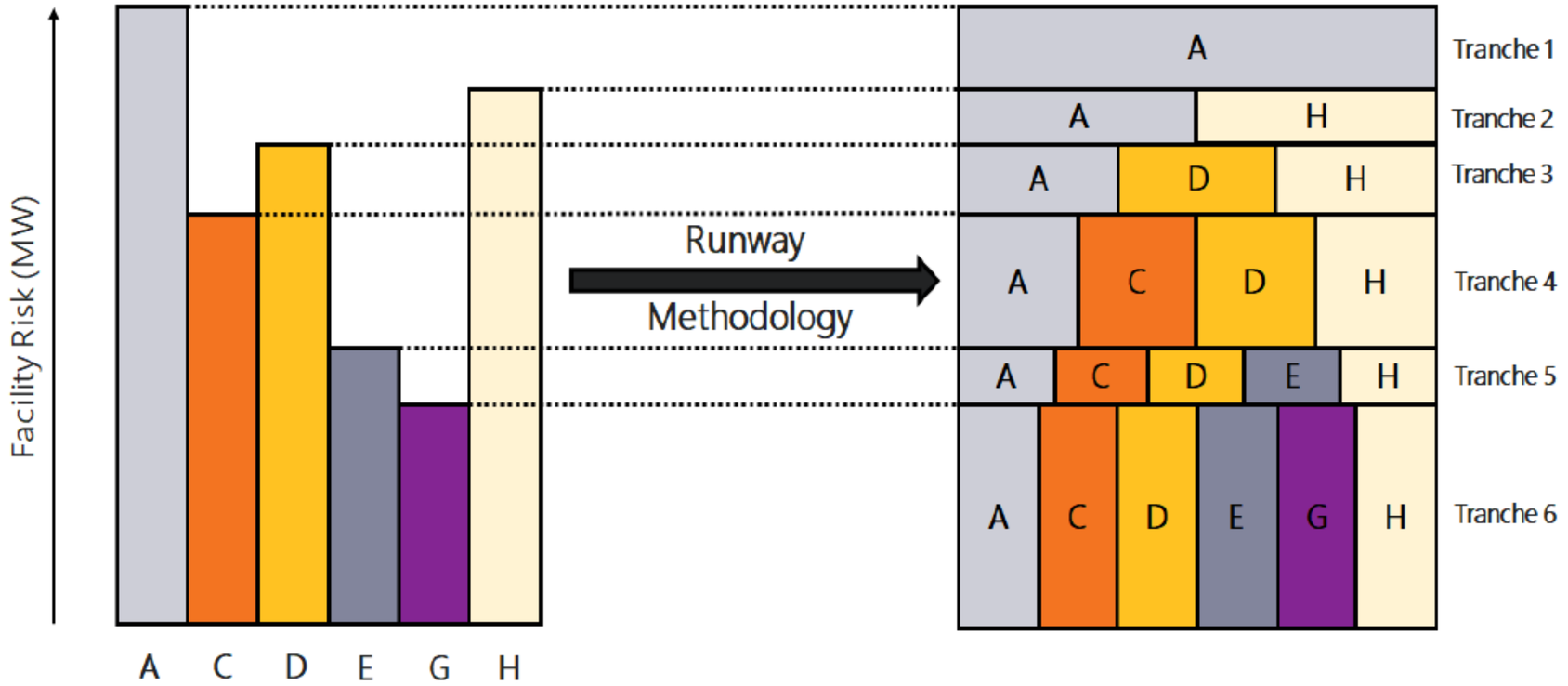
Sequential cost allocation (Shapley value)

Each unit pays for the **additional cost** that it creates



Reference: “A report describing the Wholesale Electricity Market in the South West Interconnected System”, Australian Energy Market Operator, September 2023

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Steps

1) Frequency-containment services **market clearing** (driven by largest unit)

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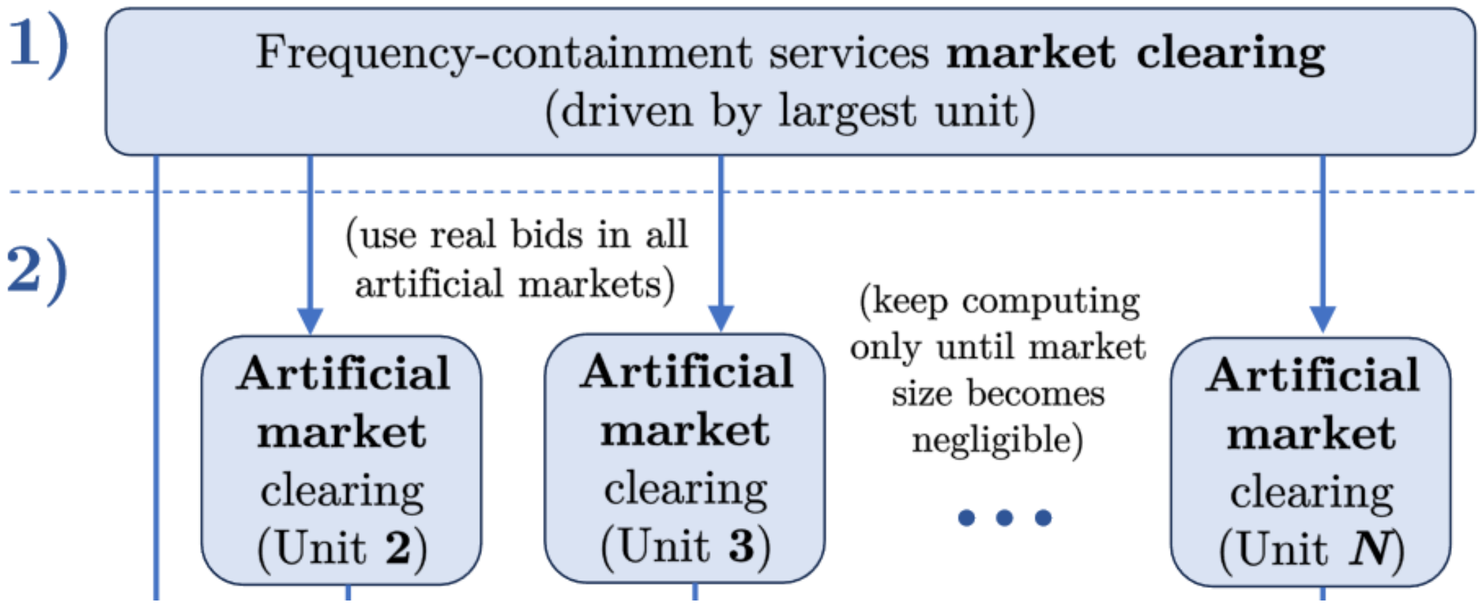
Steps



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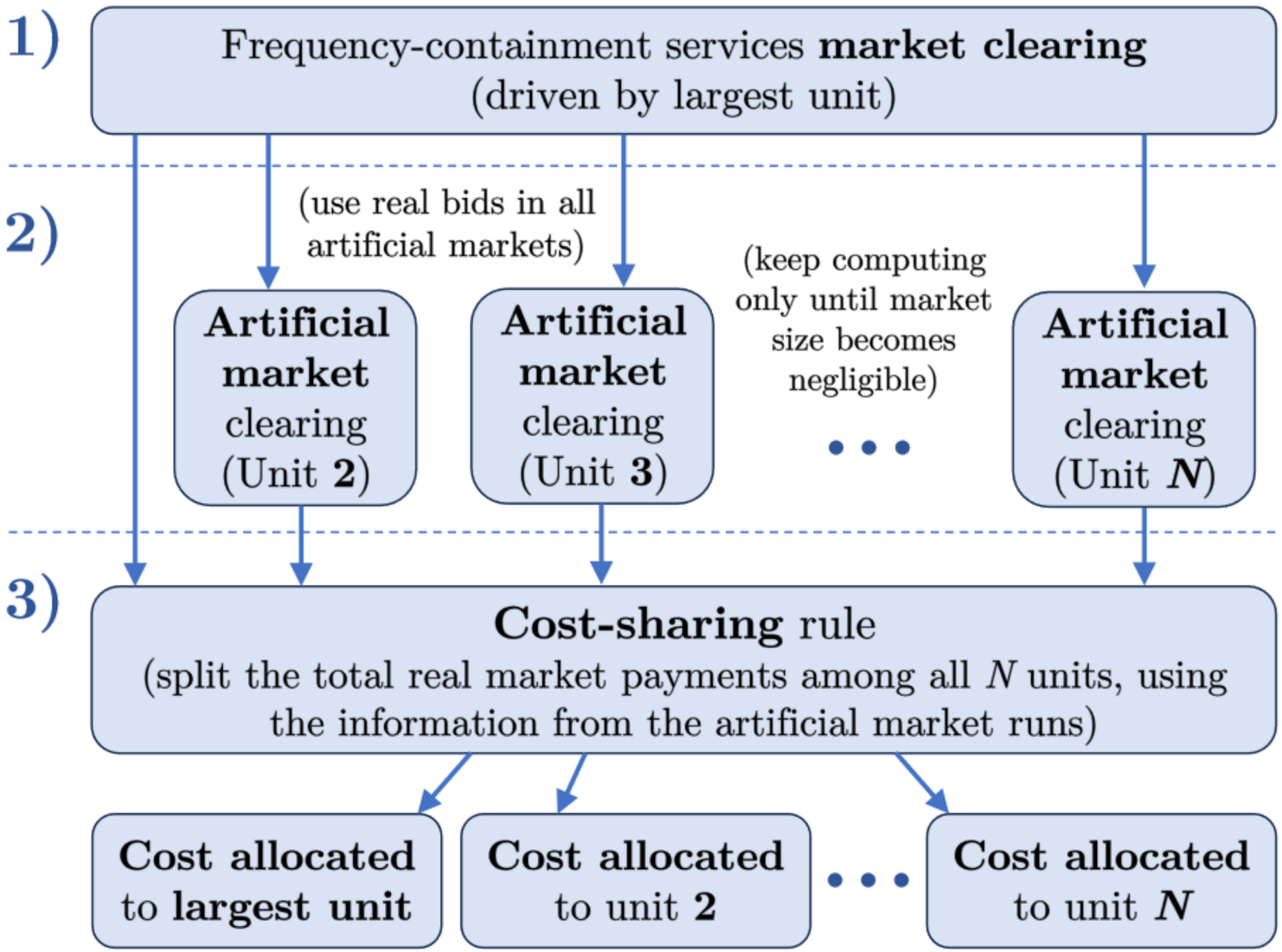
Steps



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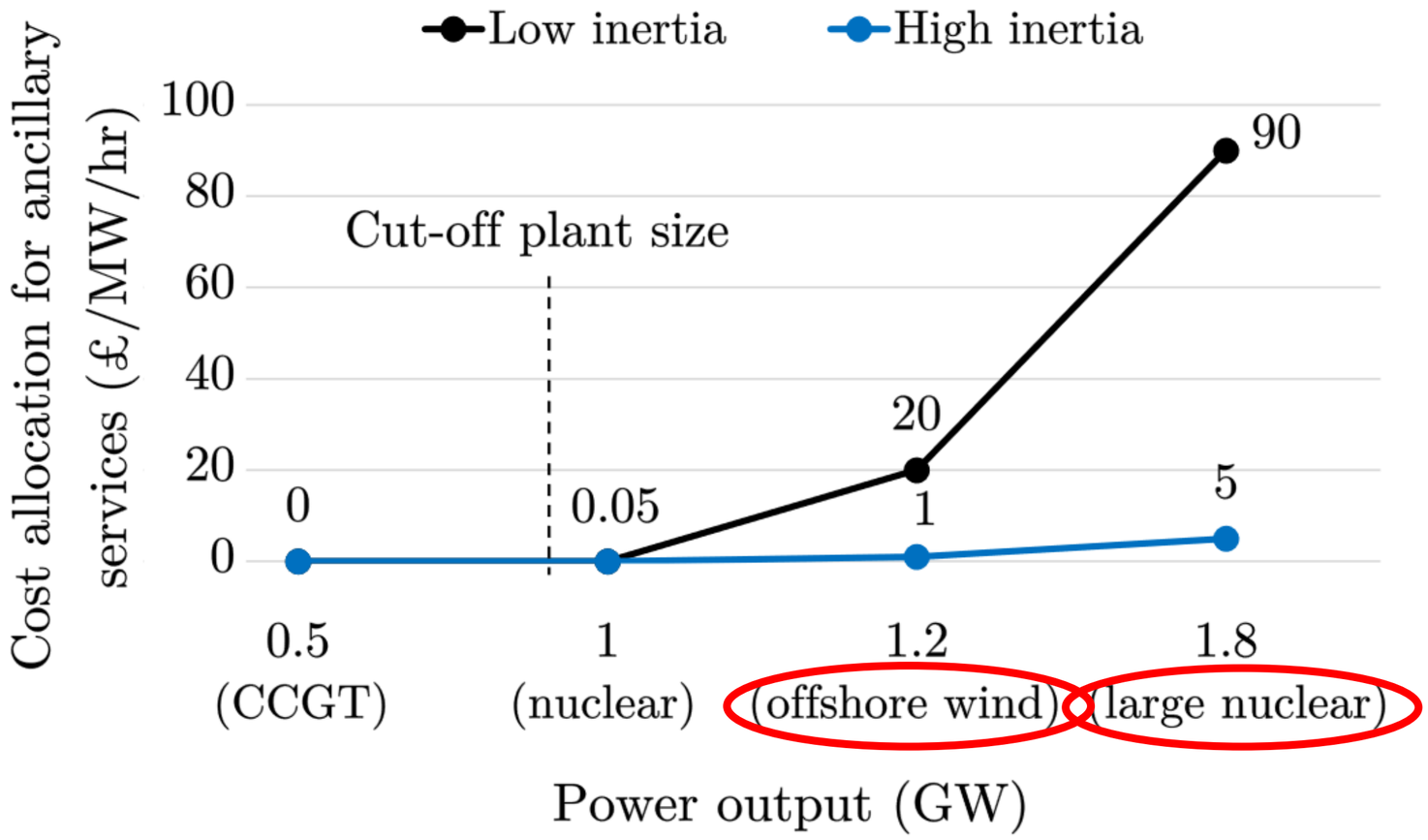
Analysis for Great Britain



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Benefits of the cost allocation

- To create **investment signals**
  - Large units would be **responsible for their system-integration cost** (*e.g.*, nuclear, offshore wind, HVDC)
  - **Costs** would still **trickle down to consumers**, but appropriate economic signals for generation would be in place
- To **incentivize flexibility**
  - Large units can reduce the cost they are allocated by **reducing power output/demand**

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Thank you for your attention!

All papers and some related code on my website:

https://badber.github.io/

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