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UK blackout on 9th of August: How should we operate a low-inertia power grid?

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What happened on 9 August?

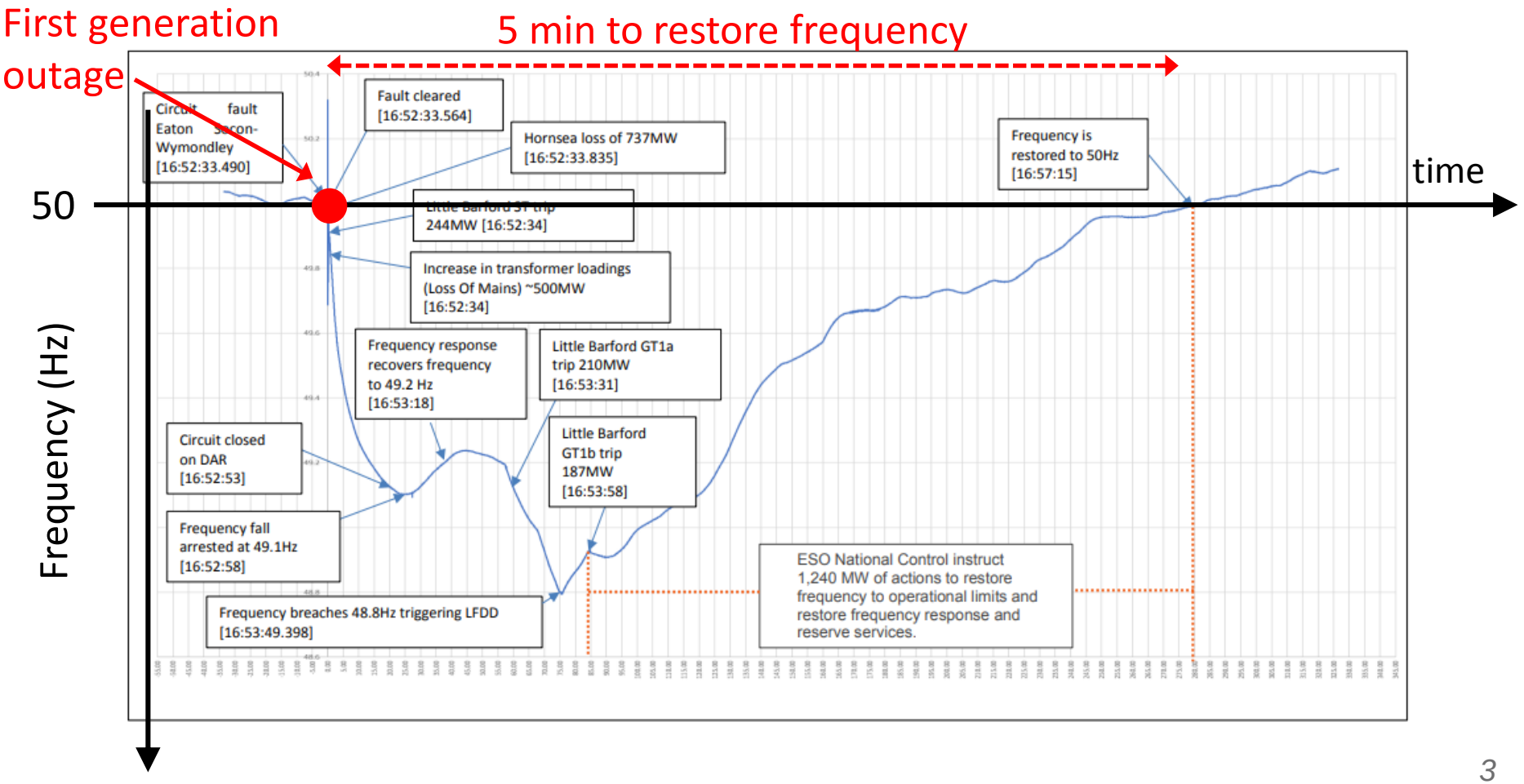
A lightning strike caused the outage of a gas plant and an offshore windfarm.

Consequences

- 1.1 million electricity customers were without power for between 15 and 50 minutes.
- Significant disruption in the rail network.
- Some other critical facilities affected: Ipswich hospital and Newcastle airport.

What happened on 9 August?

nationalgridESO Interim Report



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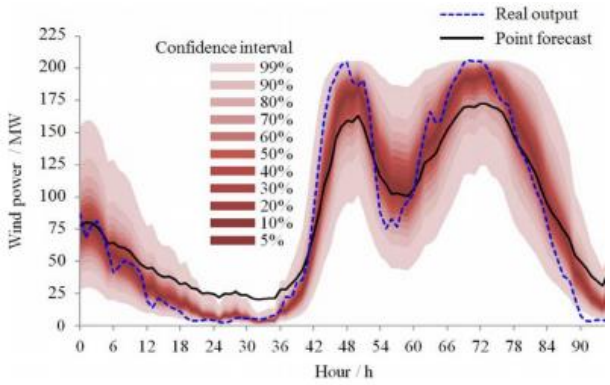
Why is it difficult to operate a grid with renewables?

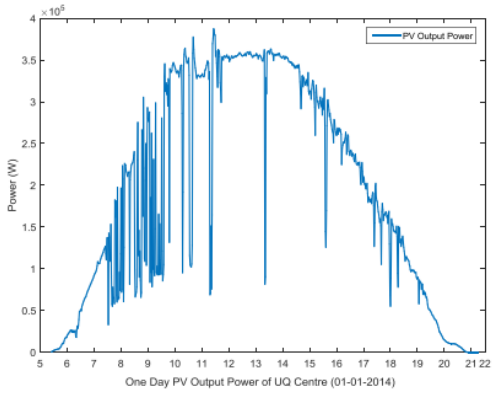
Challenges of Renewables

Uncertainty



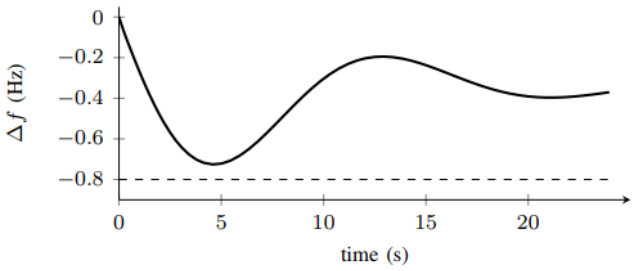
Difficult to forecast when the wind will blow

Variability



Clouds cover the sun

Low Inertia



Sources of pictures: *"On recent advances in PV output power forecast"*, Applied Energy 2016; *"Modeling Conditional Forecast Error for Wind Power in Generation Scheduling"*, IEEE Trans. on Power Systems 2014; *"Simultaneous Scheduling of Multiple Frequency Services in Stochastic Unit Commitment"*, IEEE Trans. on Power Systems 2019

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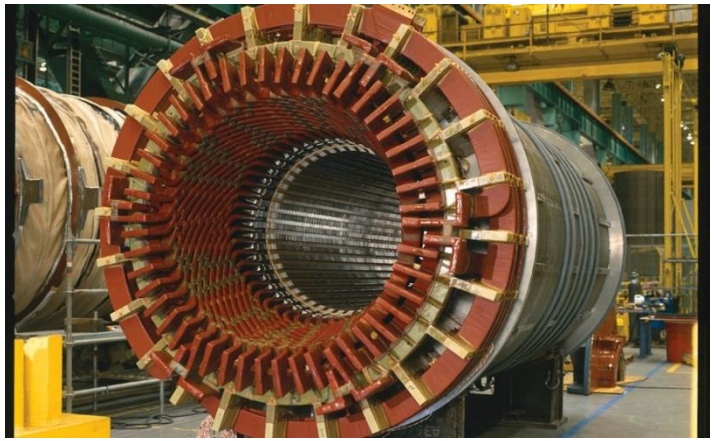
What does "low inertia" mean?

"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.

- *After a generation outage, the rotating masses slow down as they spontaneously release kinetic energy. Therefore frequency decreases.*

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!

So, would the outage not have happened if there were no renewables?

Renewables increase the risk, because frequency drops faster when there is less inertia available. But **the outage could still have happened** if there were no renewables (see outage of 2008).

My research: "insurance" to prevent outages

Swing equation:

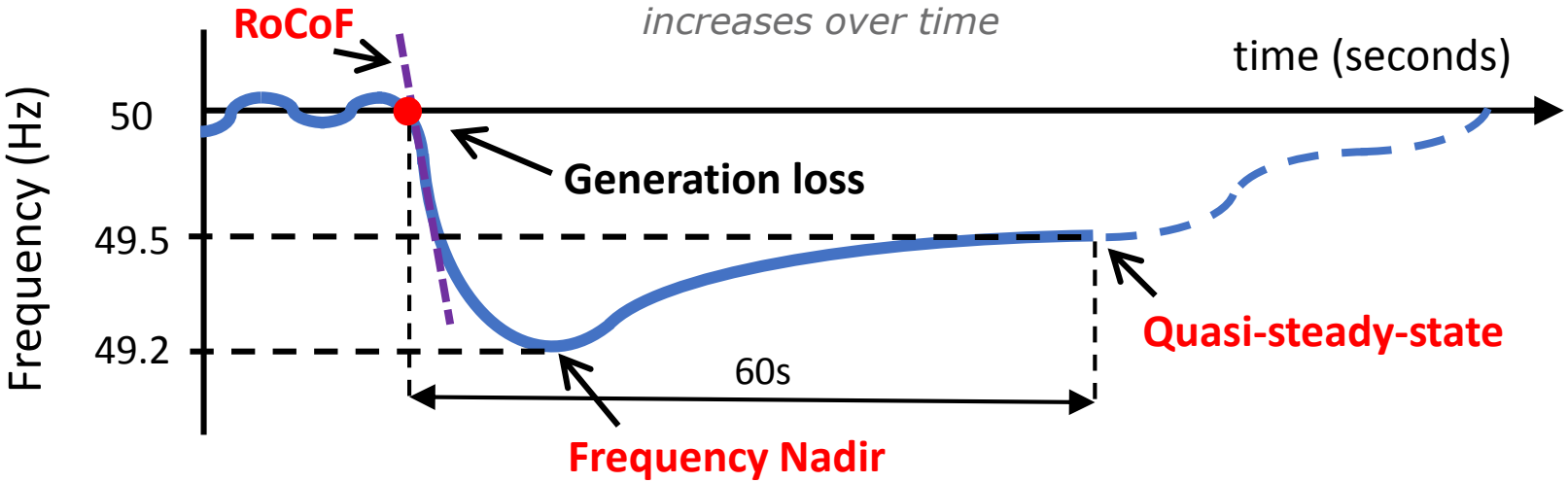
Loss of largest power infeed (N-1 requirement)

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

Power injection following loss, increases over time

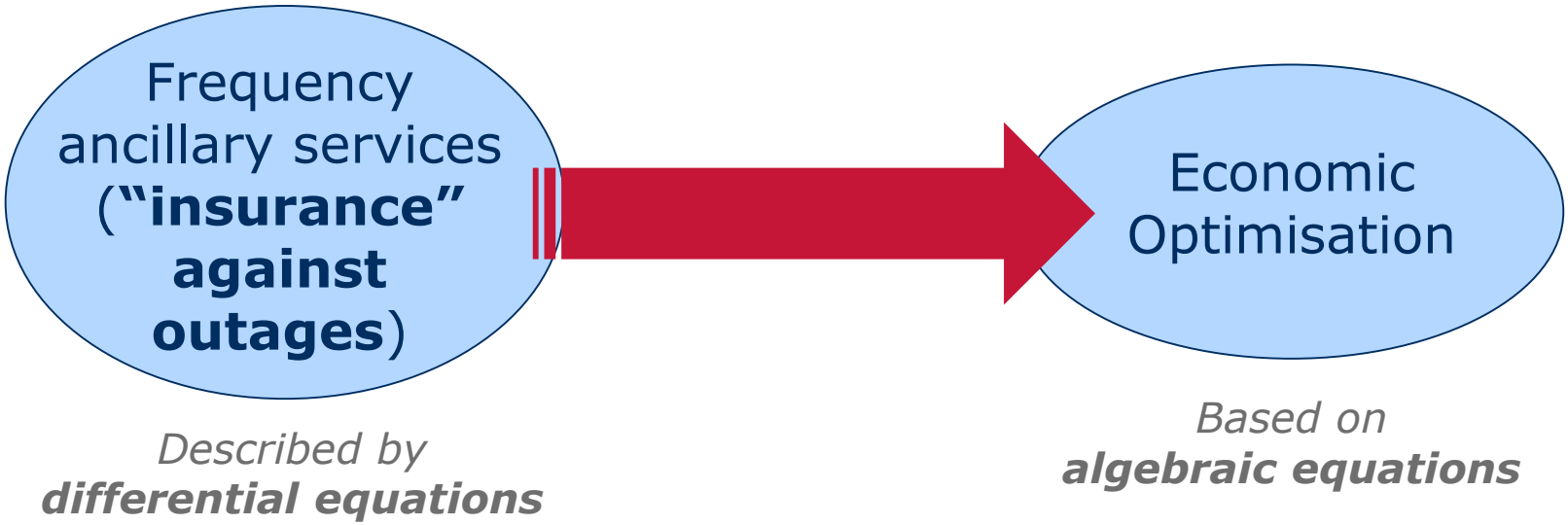
Nomenclature

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



My research

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



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

Could things have gone better on August 9?

Enough “insurance” had been bought to cover the *N*-1 outage (typical approach in most countries), but **the event was a rare *N*-2 loss**.

Should we pay for *N*-2 insurance then?

It makes economic sense to risk having an outage of this size roughly every ten years: the **operating cost of the grid would increase by more than £300M/year** for reaching this level of security.

In the future, with increasing renewables, much more insurance would be necessary for covering the *N*-2 contingency.

Could things have gone better on August 9?

Actually, **things went quite well**, this being a highly unlikely event: frequency was restored in 5 min, all load was restored within 50 min.

A **national blackout was avoided** due to disconnecting this 5% of the total load.

What could have been done differently?

Probably **prioritising load**, as the rail service disruption took much longer to be solved.

For more **info on the outage of August 9**:

- Prof. Tim Green's blog entry
- Prof. Keith Bell's blog entry
- National Grid's report

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…