Background, Aim, and Proposal

GSR027: Review of the NETS SQSS Criteria for Frequency Control that drive reserve, response and inertia holding on the GB electricity system

Specific questions

5.7. Action (1): The ESO, in consultation with the industry, should undertake a review of the SQSS requirements for holding reserve, response and system inertia.

5.7.1. This review should consider:

- The explicit impacts of distributed generation on the required level of security
- Whether it is appropriate to provide flexibility in the requirements for securing against risk events with a very low likelihood, for example on a cost / risk basis
- The costs and benefits of requiring the availability of additional reserves to secure against the risk of simultaneous loss events

5.7.2. The ESO, as the party required to operate to the standard, should carry out this review and raise modification proposals to the SQSS Panel by April 2020. This would provide the appropriate channels for industry scrutiny and transparency, and for an ultimate Ofgem decision on any required changes to the standard.

What are we trying to achieve?

- The end consumer has two key objectives:
  - a reliable supply of electricity
  - at an affordable price
- There is a natural tension between those two objectives:
  - higher reliability requirements result in higher costs to meet them
- We are trying to facilitate the electricity industry to make an informed decision on finding the right balance between those two objectives

What are we trying to achieve?

Key questions

1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

Structure

Frequency	Risks	Control	Proposal
Primary legislation	Transmission-connected	Mitigating risks	Frequency Risk & Control Report
SQSS implementation	Loss of Mains	Interactions and complexity	
Real-life impact	Combined events	Projects Pipeline	
	Likelihood of events		

Frequency Standards

The Electricity Supply Regulations 1988

30. Declaration of phases, frequency and voltage at supply terminals

…

Provided that, unless otherwise agreed between the supplier and the consumer, the frequency to be declared shall be 50 hertz and the voltage to be declared in respect of a low voltage supply shall be 240 volts between the phase and neutral conductors at the supply terminals.

(2) For the purposes of this regulation, and unless otherwise agreed by the consumer, the permitted variations are

(a) a variation not exceeding one per cent above or below the declared frequency; …

…so what does “unless otherwise agreed by the consumer” mean?

Security and Quality of Supply Standard

Unacceptable Frequency Conditions

These are conditions where:

i) the steady state frequency falls outside the statutory limits of 49.5Hz to 50.5Hz;

or

ii) a transient frequency deviation on the MITS persists outside the above statutory limits and does not recover to within 49.5Hz to 50.5Hz within 60 seconds.

Transient frequency deviations outside the limits of 49.5Hz and 50.5Hz shall only occur at intervals which ought to reasonably be considered as infrequent.

Key Questions

Key questions

1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

Question 1: Risks

a. What is considered “infrequent”?

b. What happens if you go outside the limits of 50.0Hz ± 1%?

c. What could cause you to go outside the limits, and by how much?

d. How often could that happen?

Question 1: Risks

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GSR015: Normal Infeed Loss Risk

“It is important that Grid continues to maintain frequency quality*, and our support for GSR015 is on the basis that, as NG assumes, loss events of between 1GW and 1.32GW do not become* more frequent than the current average of about 4 times per year – so that they remain rare*. If this is breached, GSR015 should be reviewed carefully, as it is unlikely to then remain appropriate.”*

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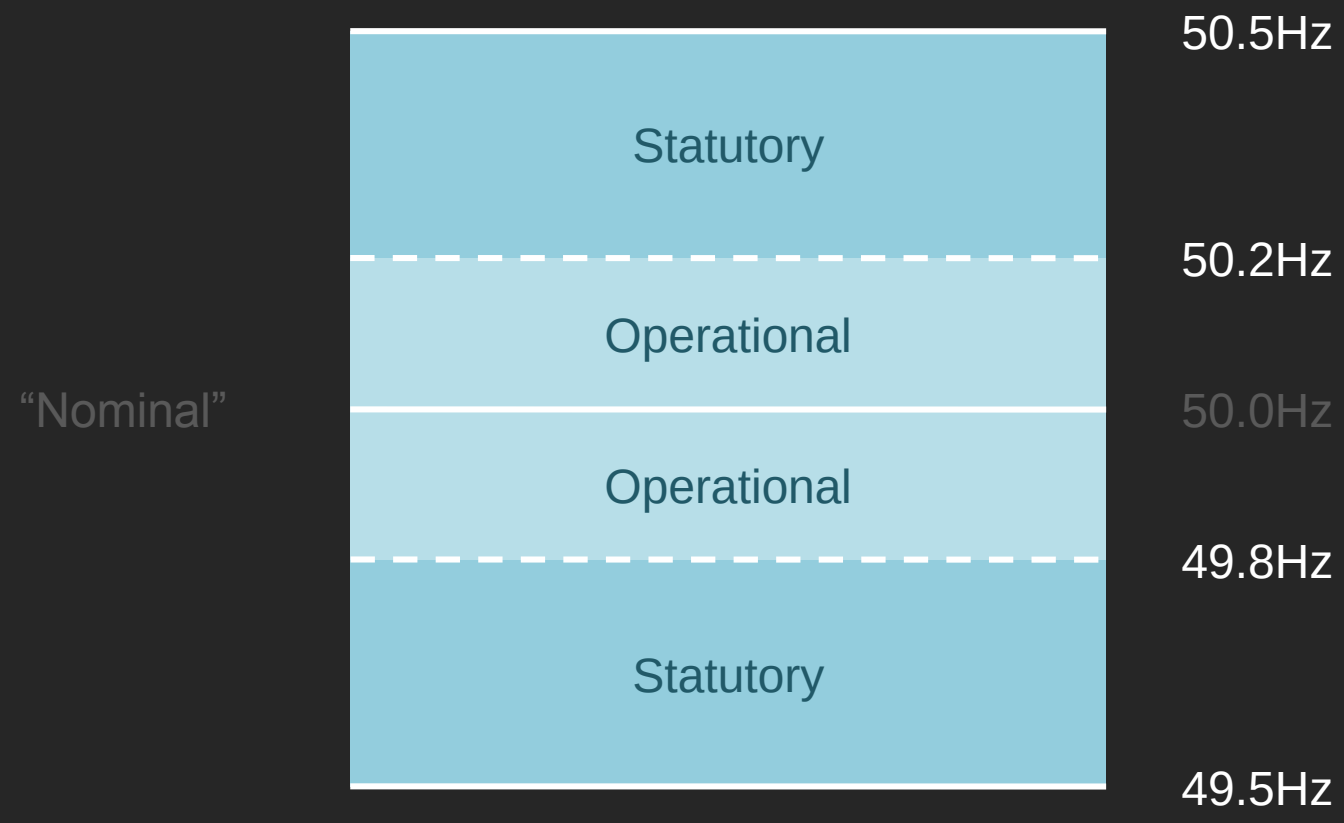
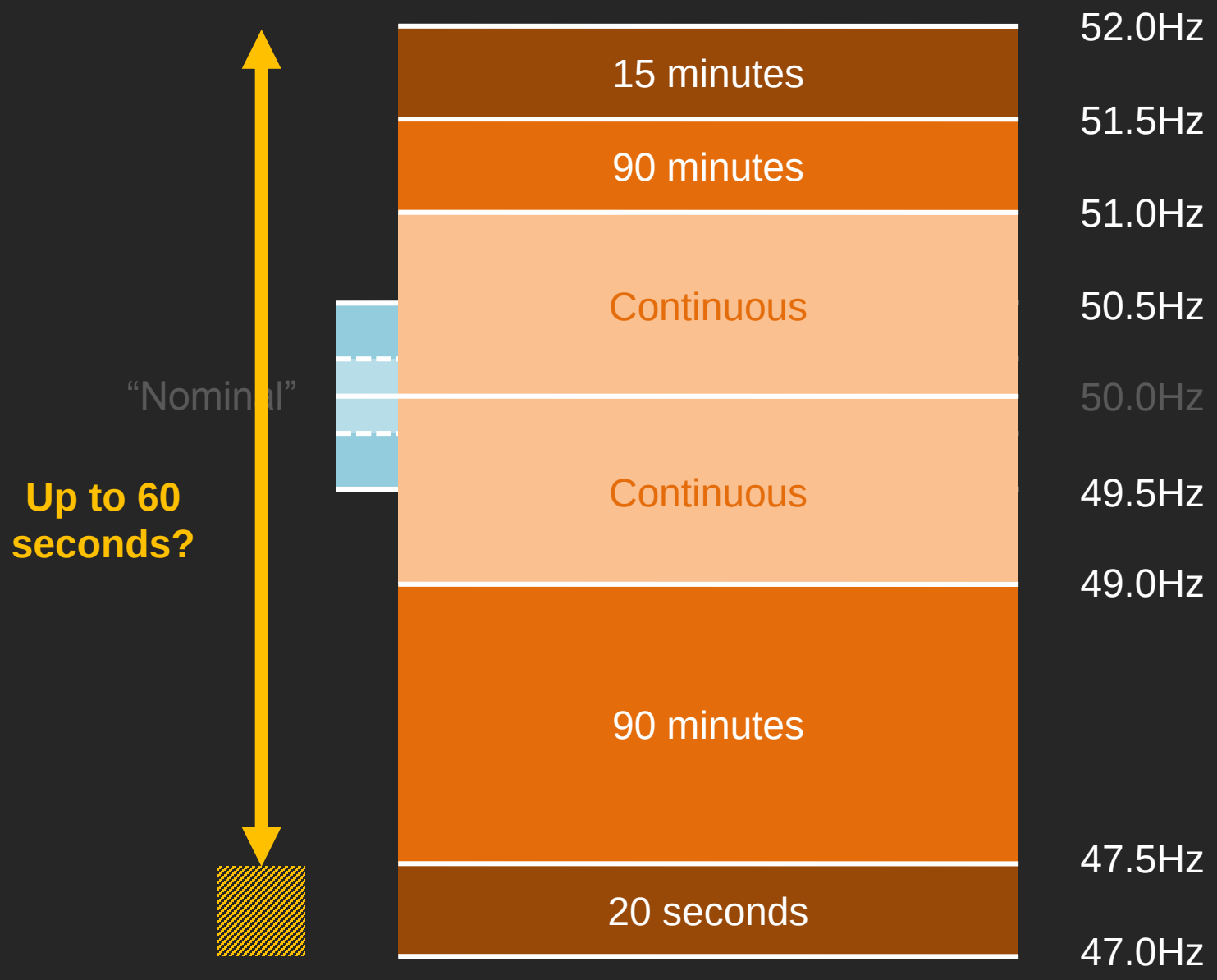
d. How often could that happen?

Frequency Standards: How far outside 50.0Hz ± 1%?



Frequency Standards: How far outside 50.0Hz ± 1%?



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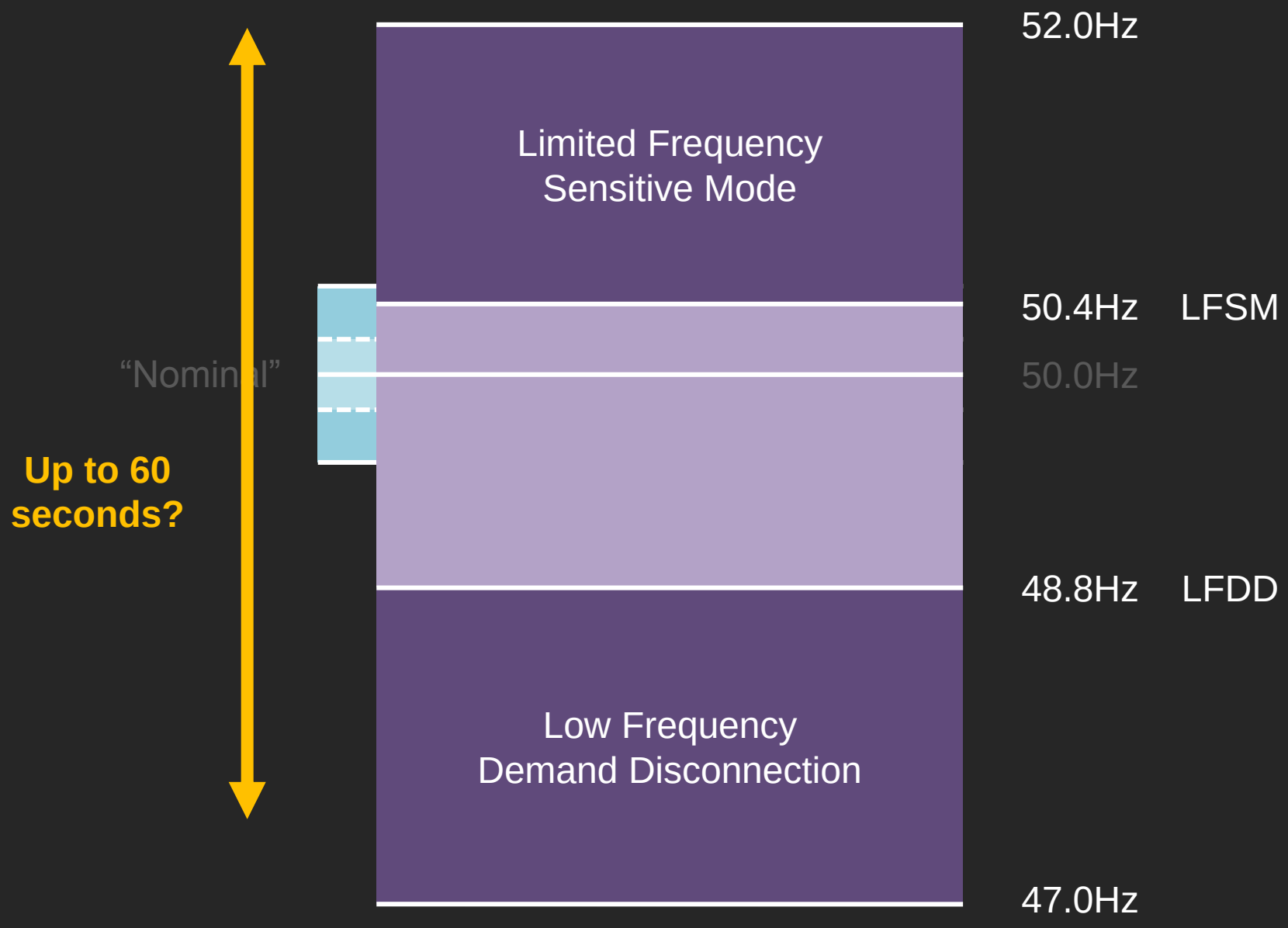

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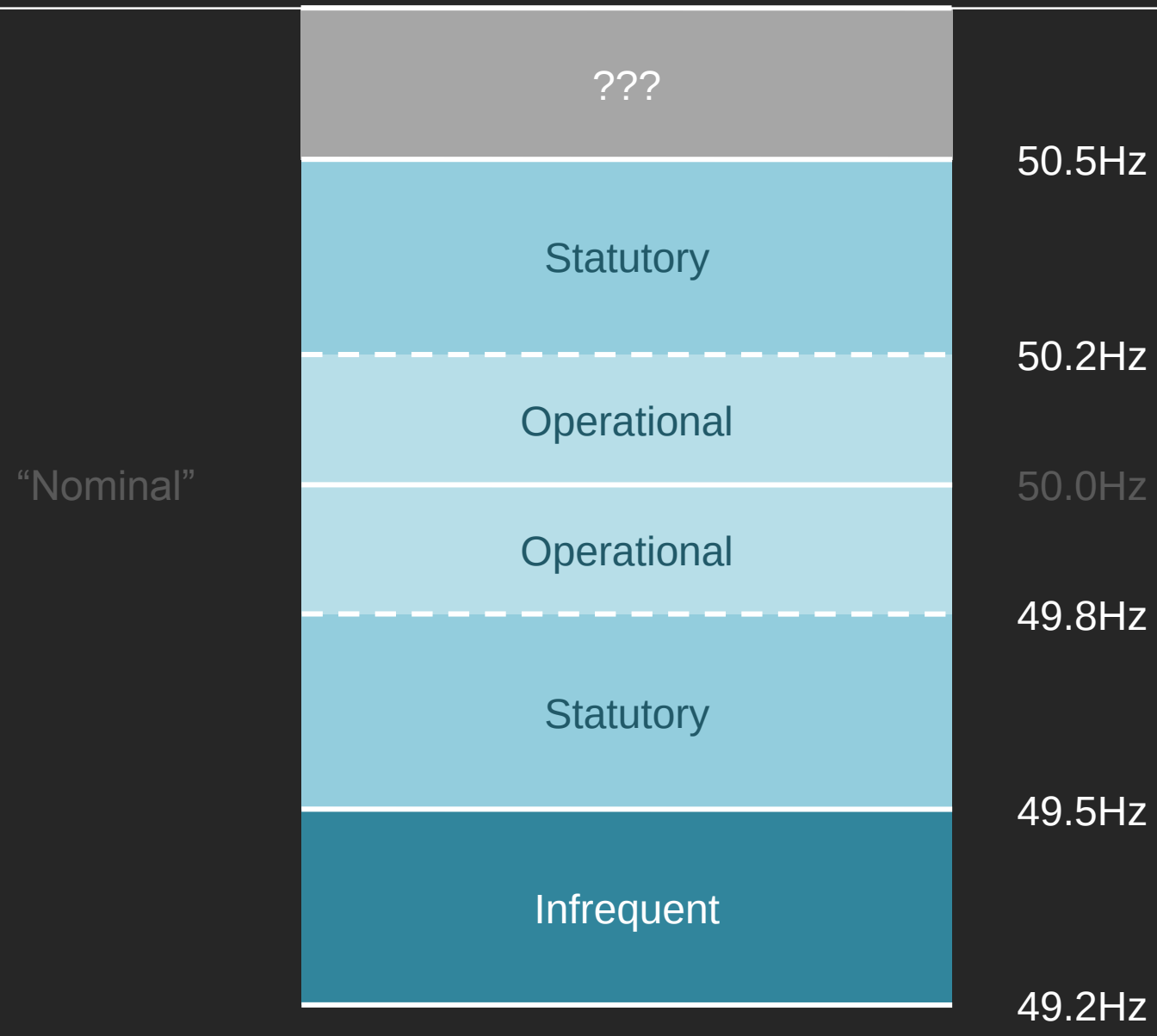

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Depends on the size of the frequency deviation:

- How often frequency goes outside the limits of 50.0Hz ± 1%
- How often the LFDD scheme is activated

What can cause frequency deviations?

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c. What could cause you to go outside the limits, and by how much?

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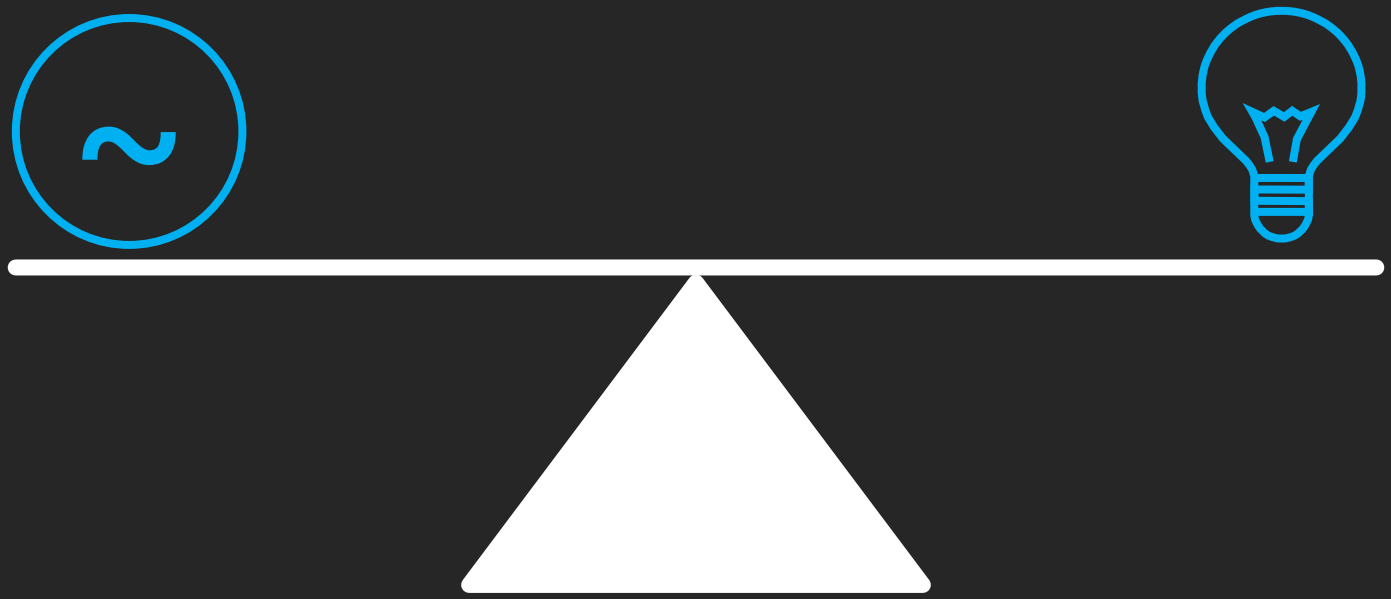
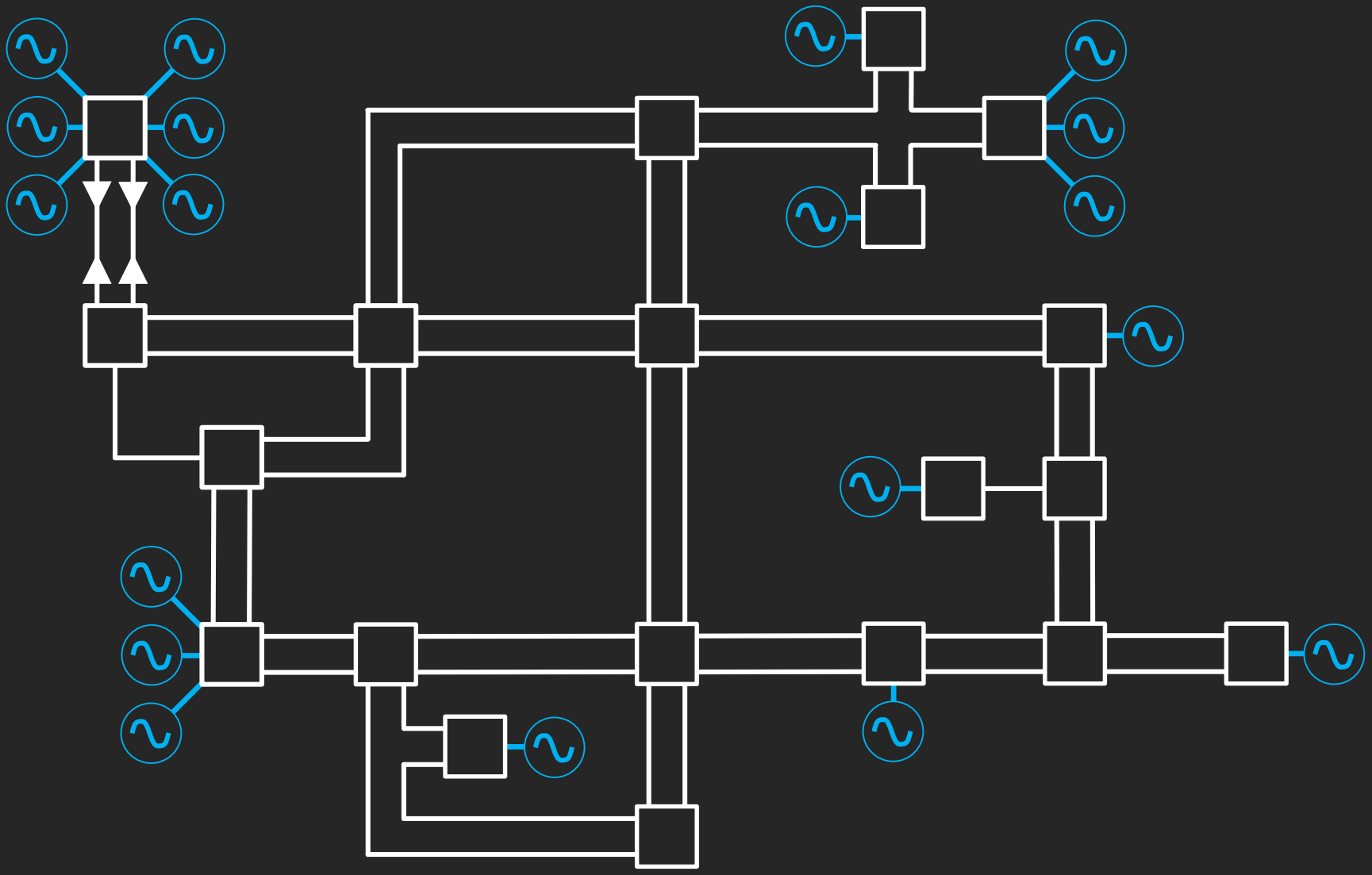
Frequency Standards: What causes deviations?



Generation = Demand

Frequency = ???

Event types



BMU | Bar / MC | Single | Double | Other

Question 1: Risks

a. What is considered “infrequent”?

b. What happens if you go outside the limits of 50.0Hz ± 1%?

c. What could cause you to go outside the limits, and by how much?

d. How often could that happen?

A variety of events, including:

- BMU loss (infeed loss)
- Busbars or Mesh Corners fault
- Single circuit fault
- Double circuit fault
- Other faults

Question 1: Risks

a. What is considered “infrequent”?

b. What happens if you go outside the limits of 50.0Hz ± 1%?

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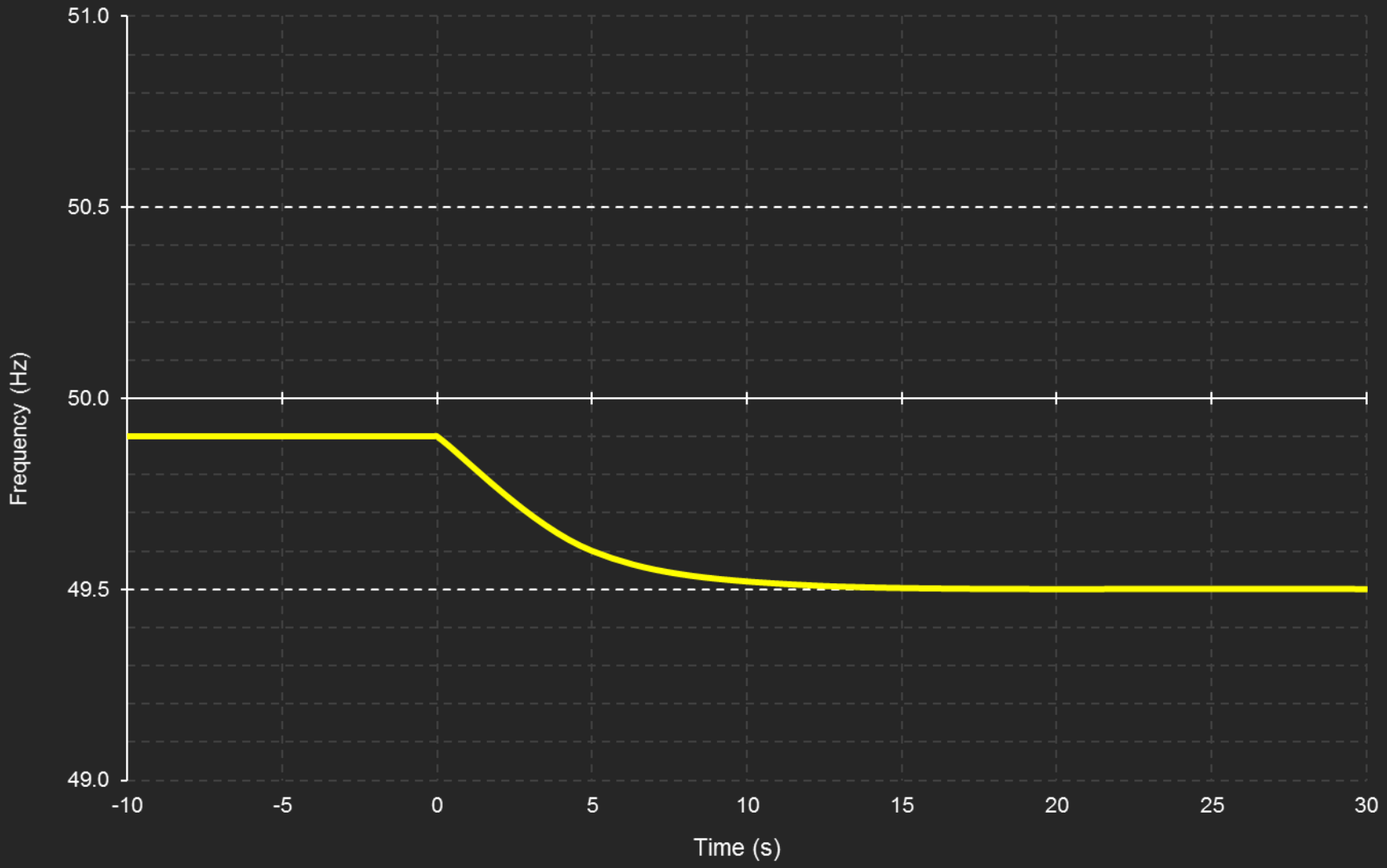
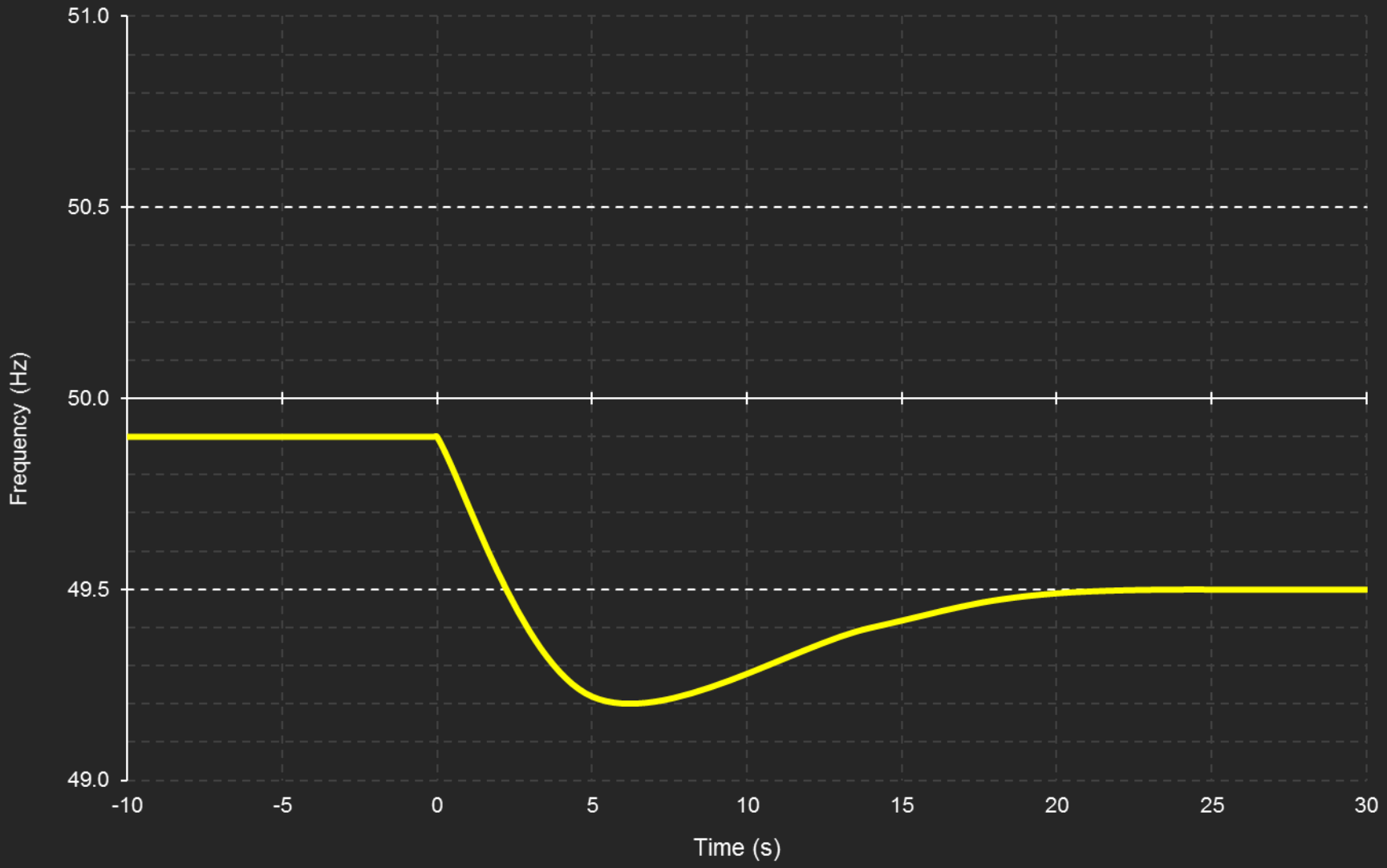
Managing frequency

In the event of a fault…



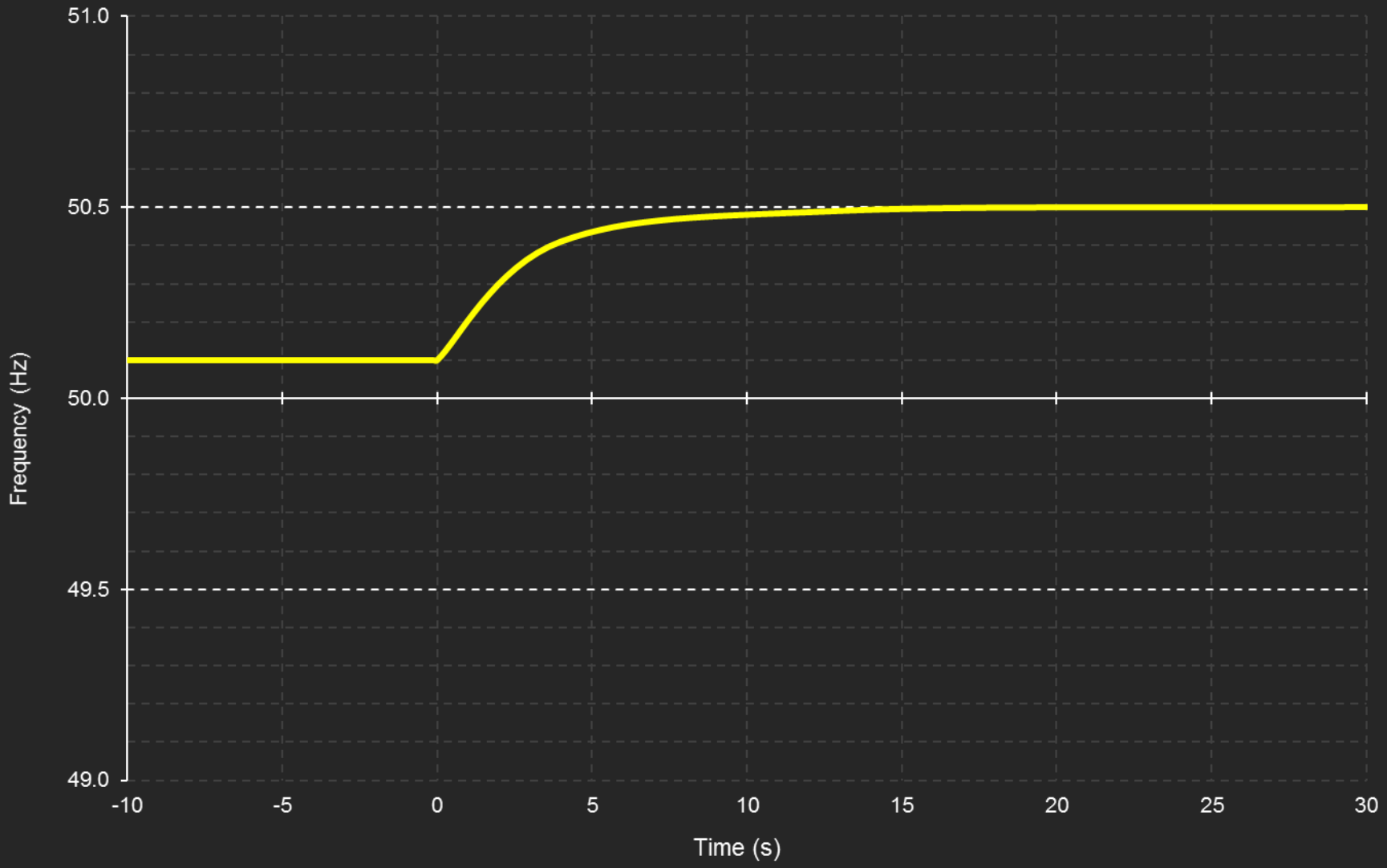
Generation loss (small)

In the event of a fault…



Generation loss (large)

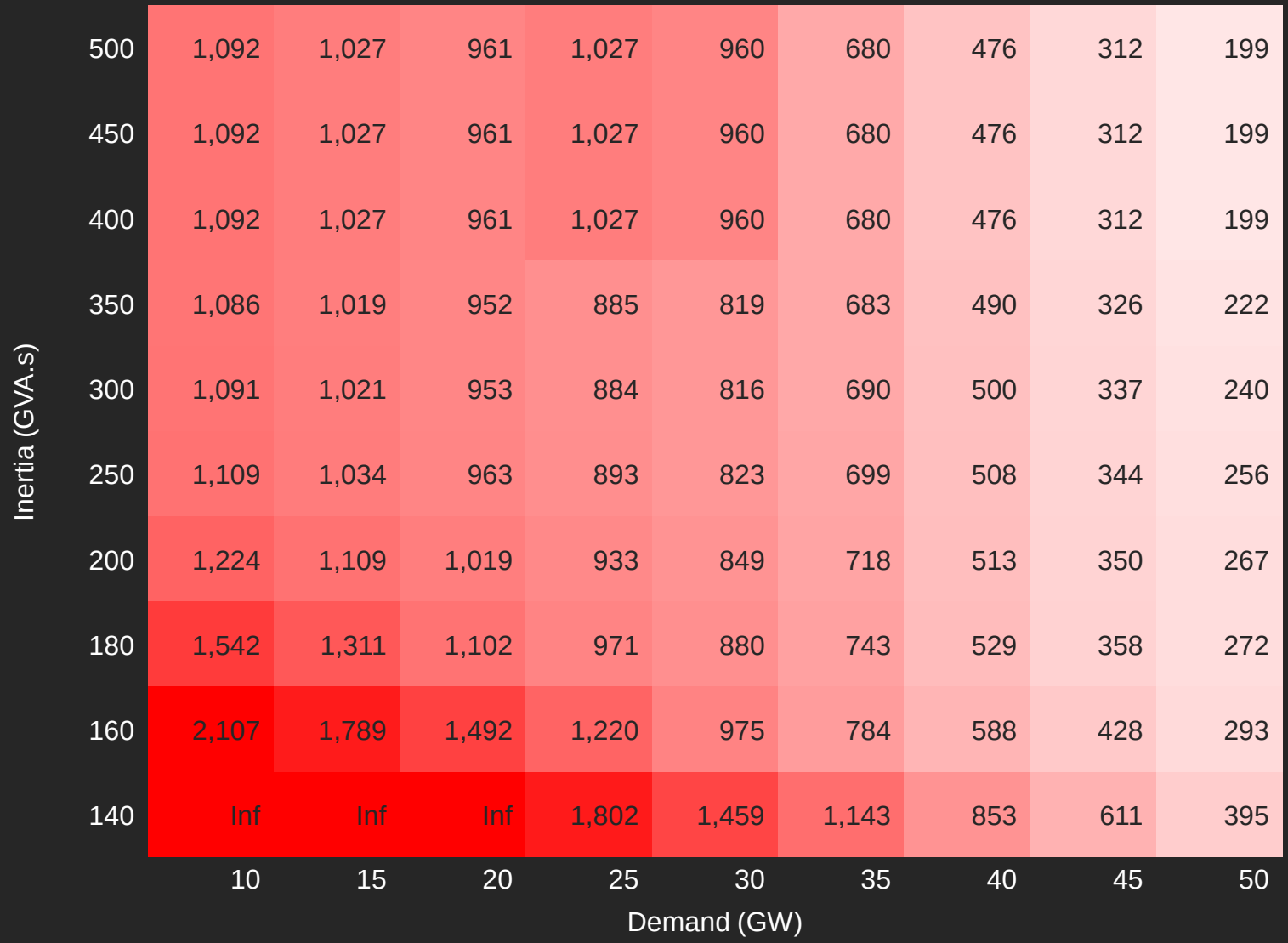
In the event of a fault…



Demand loss (any size)

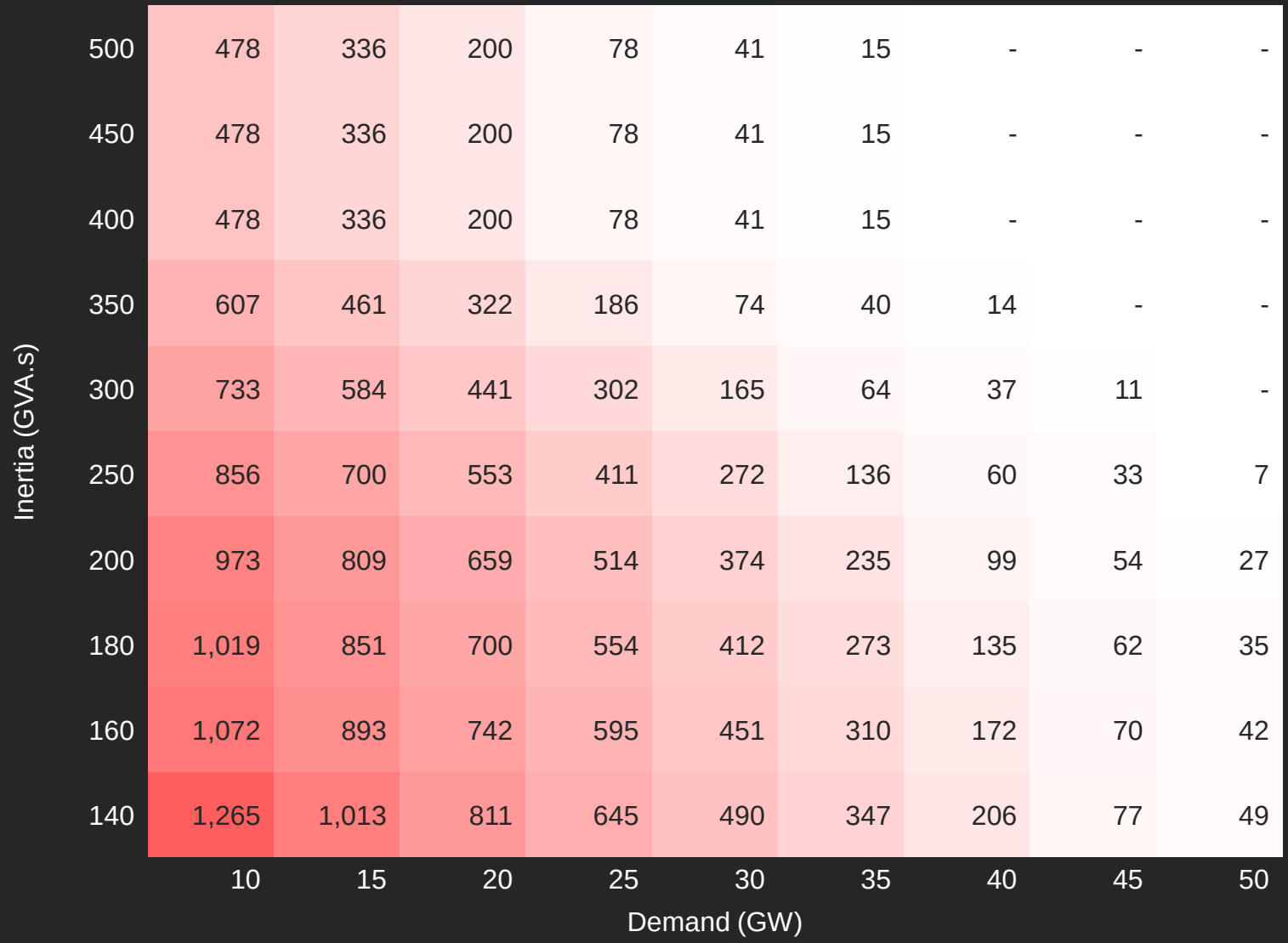
Inertia & demand: effect on response requirements

Example Primary response requirements for 1,000MW loss to 0.5Hz



Inertia & demand: effect on response requirements

Example Primary response requirements for 1,260MW loss to 0.8Hz



Inertia (GVA.s)	10	15	20	25	30	35	40	45	50
500	478	336	200	78	41	15	-	-	-
450	478	336	200	78	41	15	-	-	-
400	478	336	200	78	41	15	-	-	-
350	607	461	322	186	74	40	14	-	-
300	733	584	441	302	165	64	37	11	-
250	856	700	553	411	272	136	60	33	7
200	973	809	659	514	374	235	99	54	27
180	1,019	851	700	554	412	273	135	62	35
160	1,072	893	742	595	451	310	172	70	42
140	1,265	1,013	811	645	490	347	206	77	49

Demand (GW)

Question 1: Risks

a. What is considered “infrequent”?

b. What happens if you go outside the limits of 50.0Hz ± 1%?

c. What could cause you to go outside the limits, and by how much?

d. How often could that happen?

- How far outside depends on:
  - the size of the loss
  - the inertia of the system
  - how much response you’re holding, and what type

Next question: What size losses are out there?

Structure

Frequency	Risks	Control	Proposal
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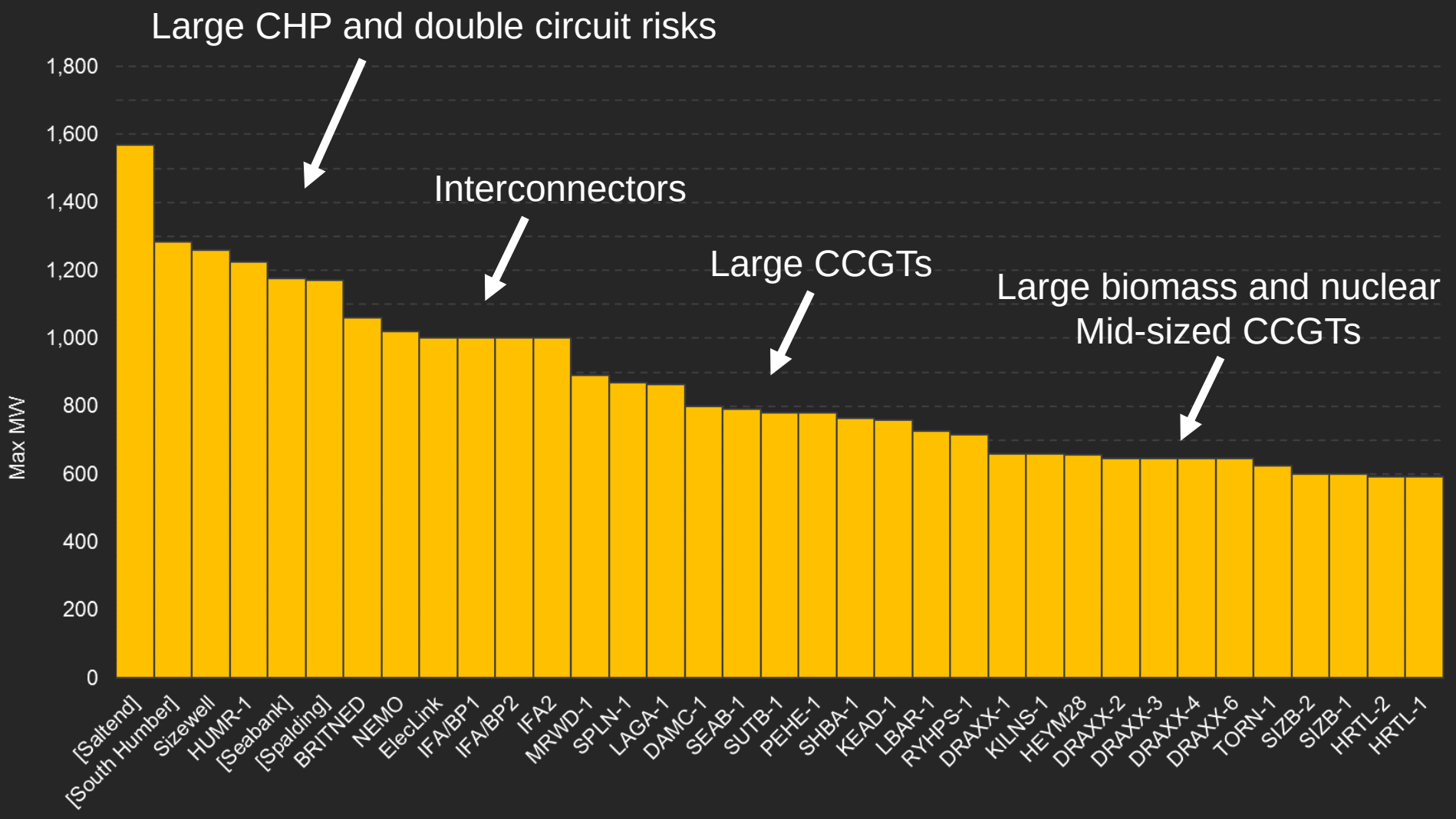
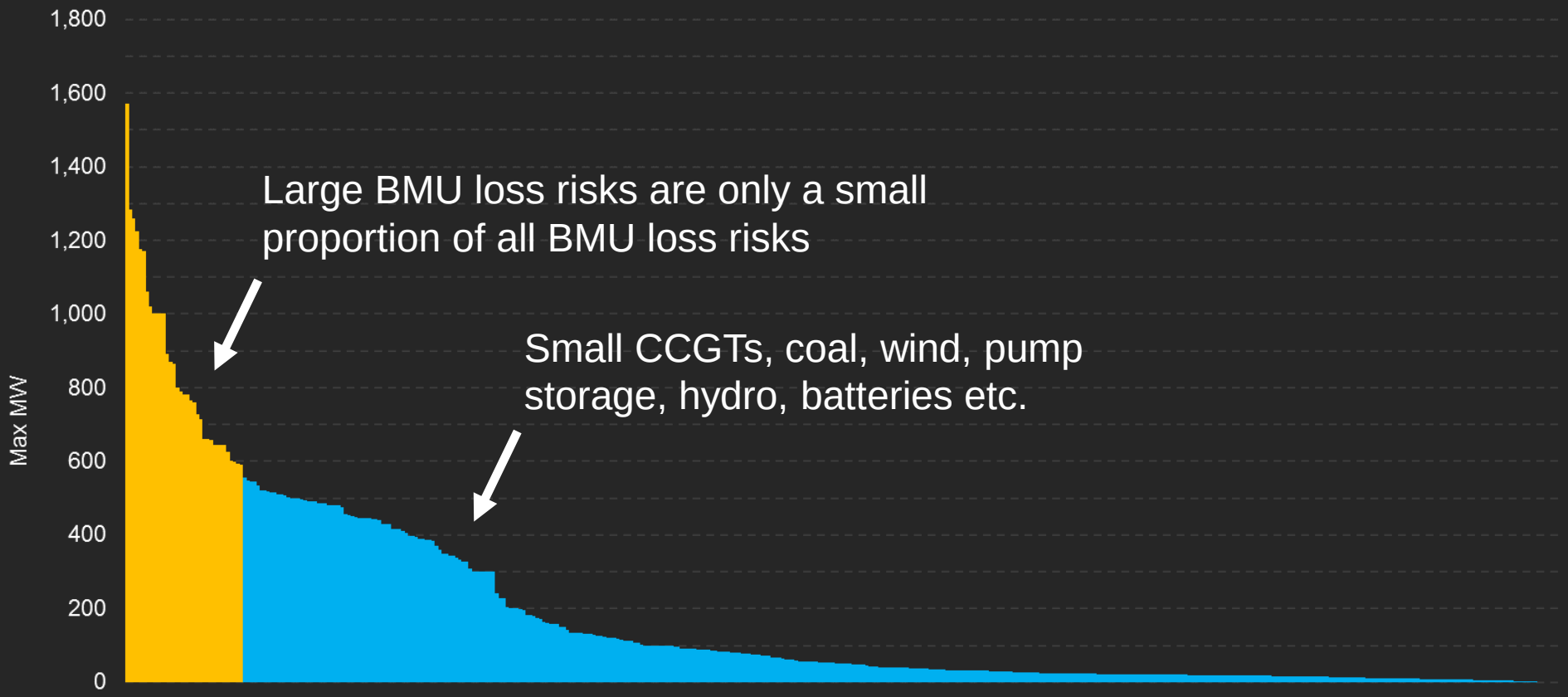
Risks

Transmission-connected risks

Transmission-connected risks



Transmission-connected risks



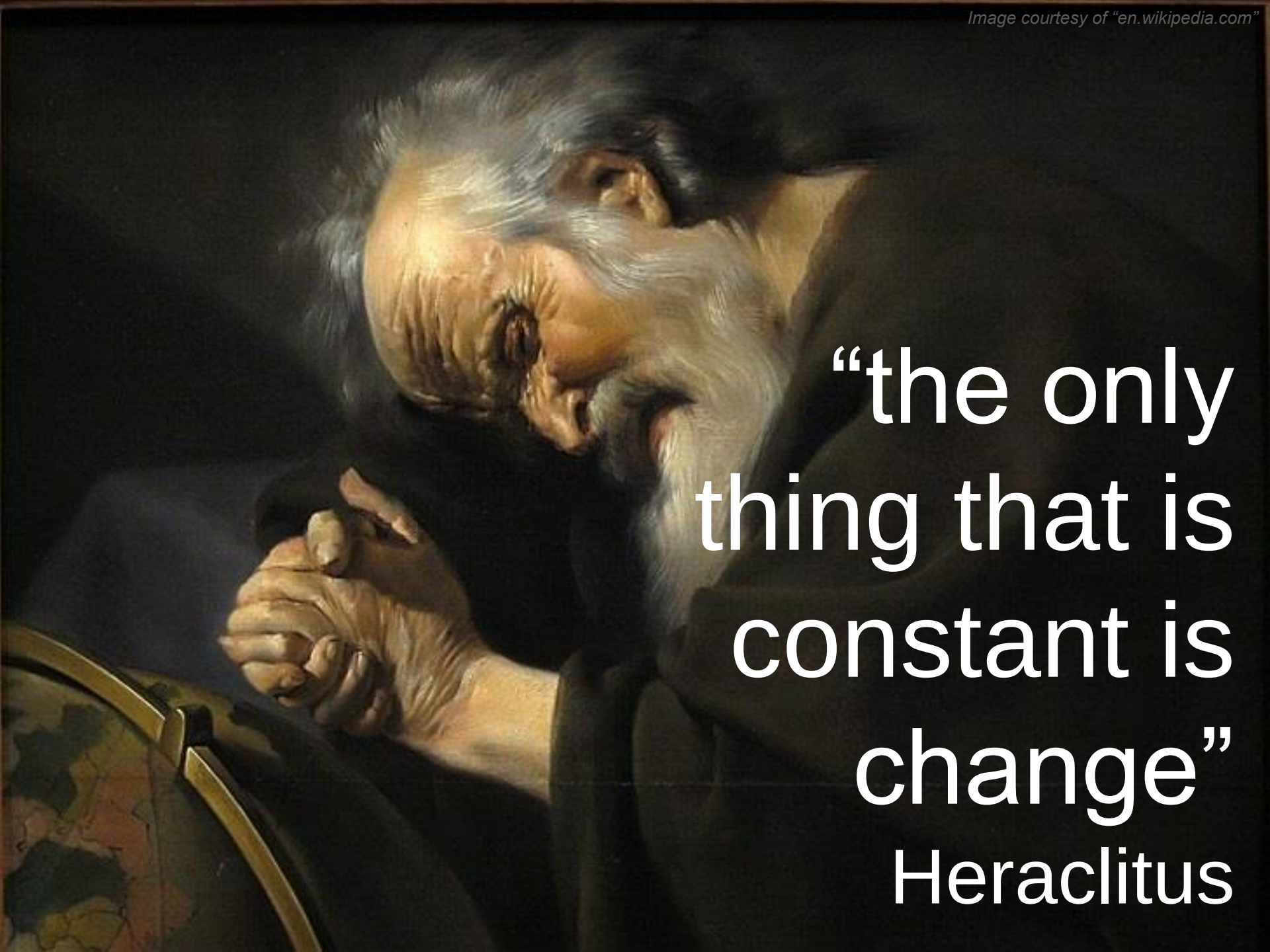


Image courtesy of “en.wikipedia.com”
“the only thing that is constant is change”
Heraclitus

In the news…

Is there enough electricity? National Grid reacts to fossil-fuel vehicle ban

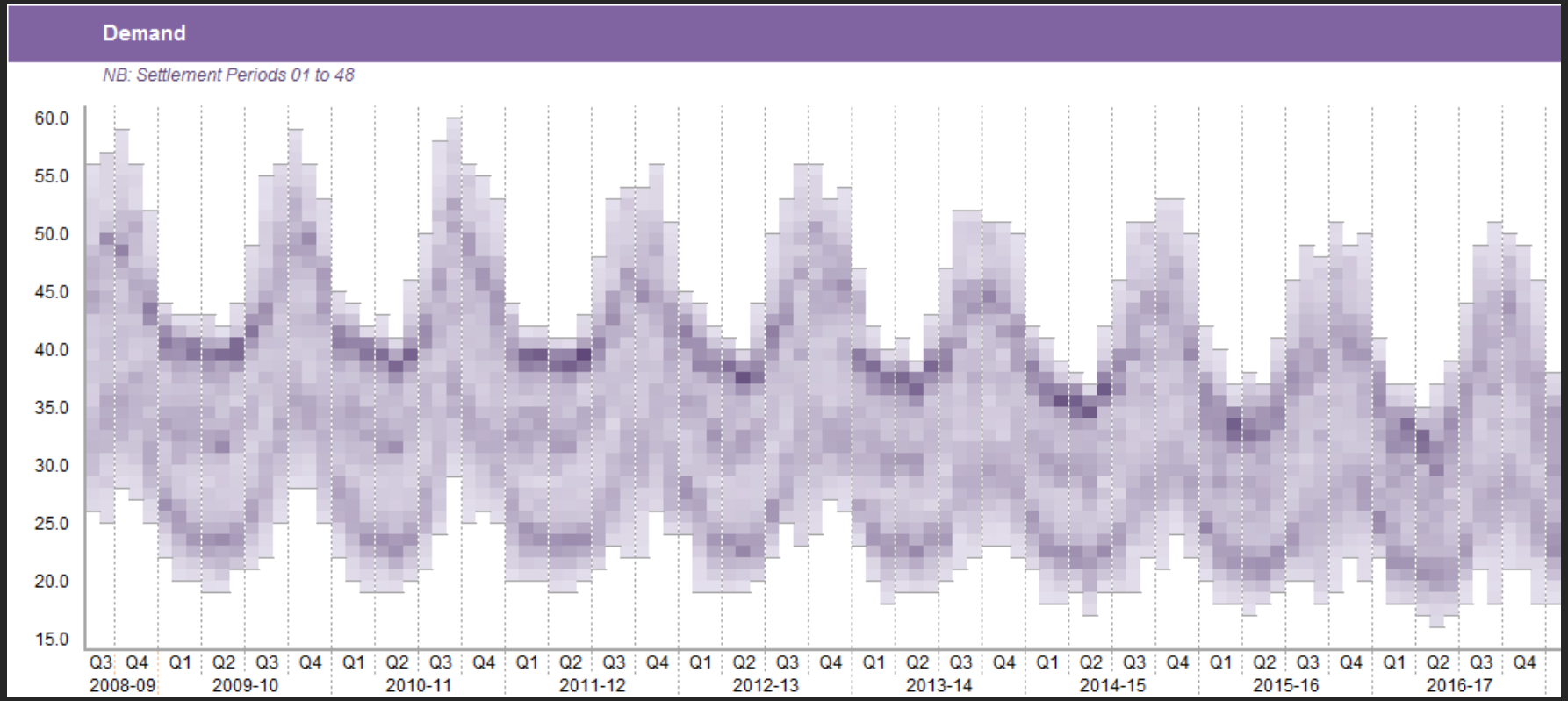
Solar power breaks UK records thanks to sunny weather

Charging ahead: Welsh battery scheme may aid growth of green energy

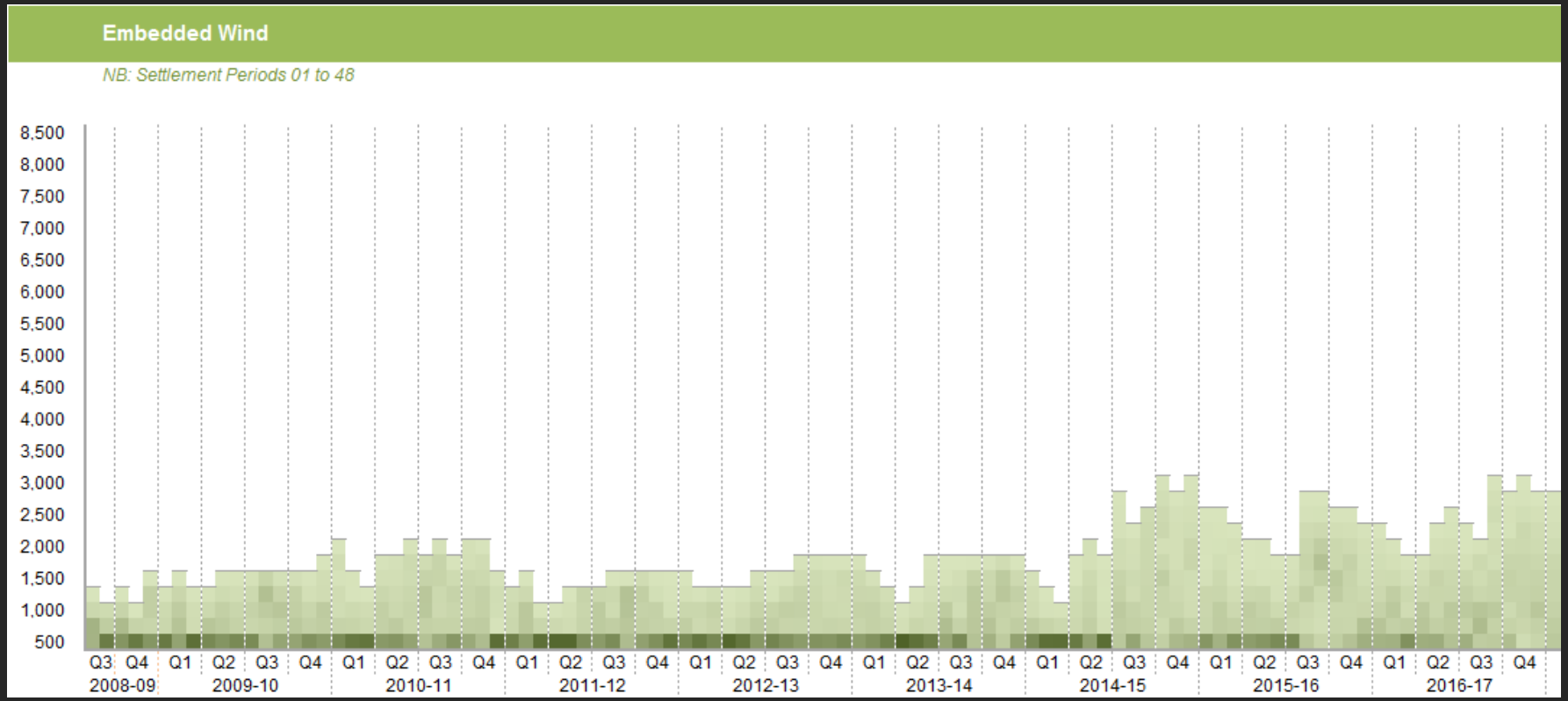
All it took was an anchor ... how a storm took down half the UK's electricity link to France

https://www.theguardian.com/business/nationalgrid

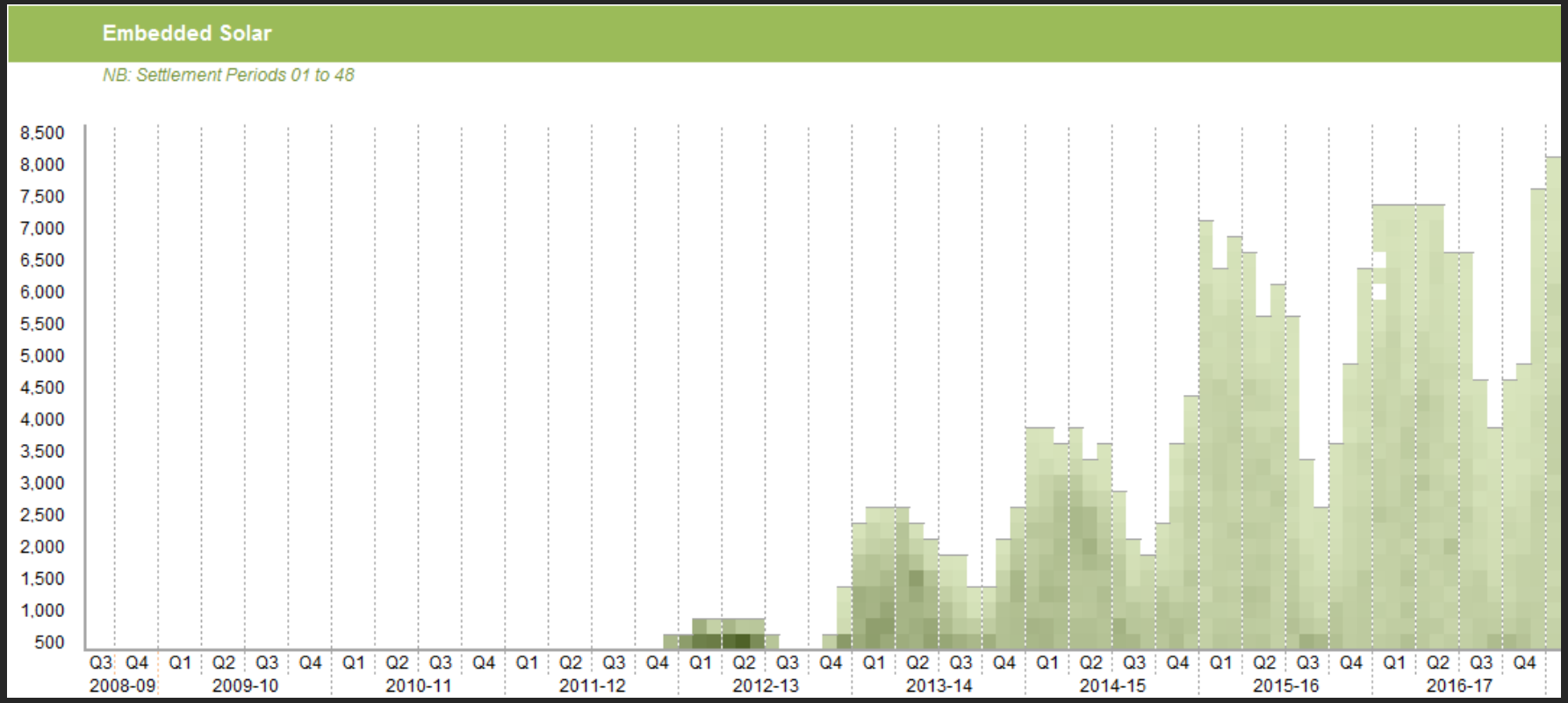
Evolution of Demand



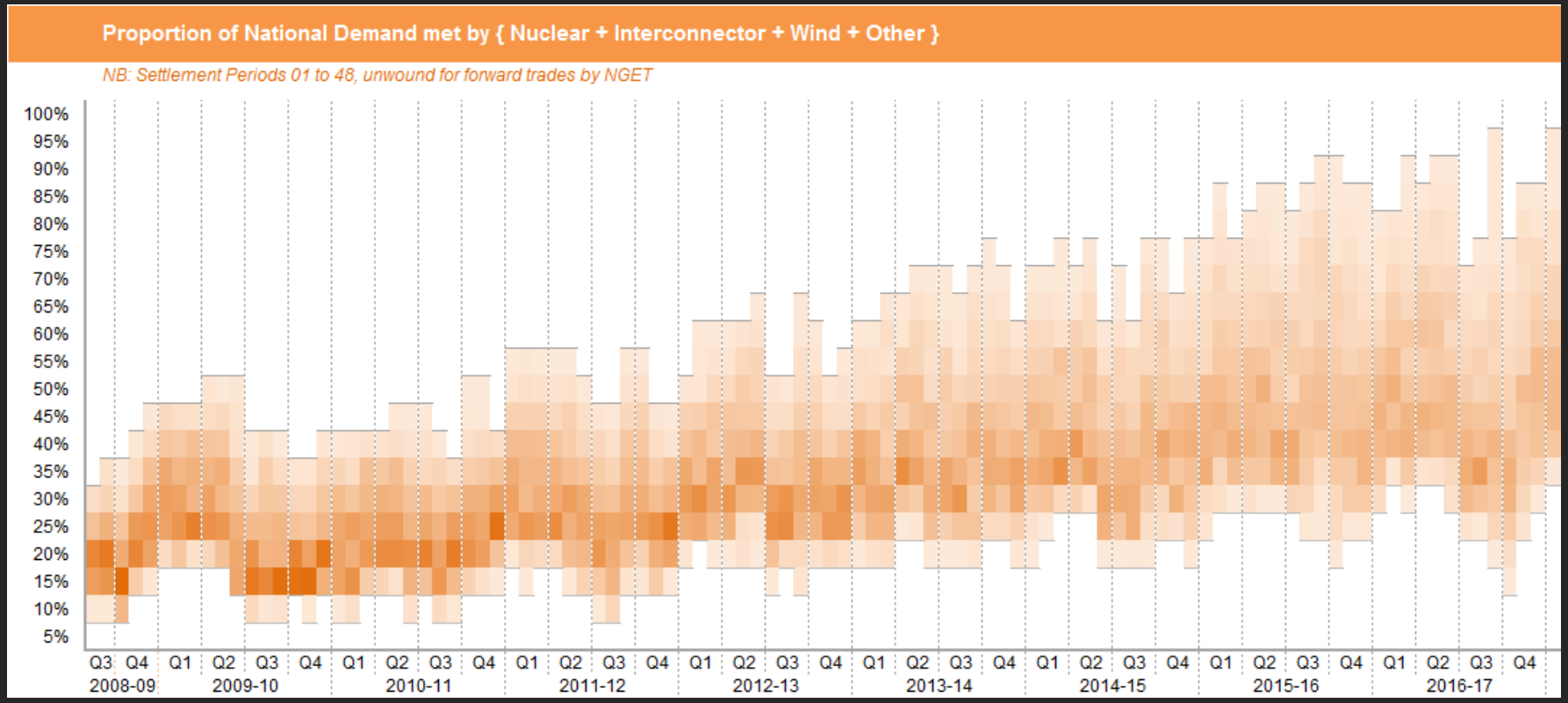
Evolution of Embedded Wind



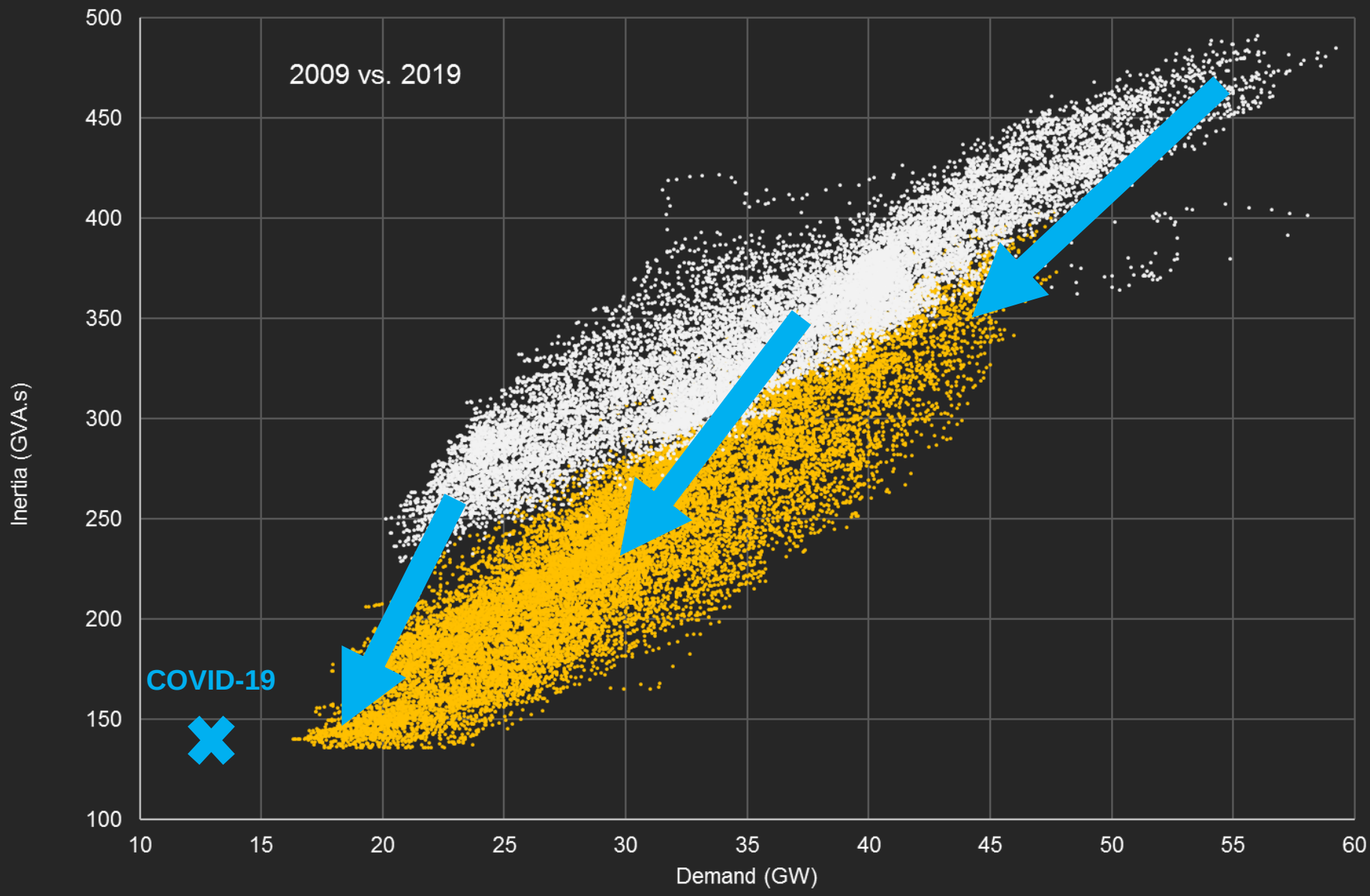
Evolution of Embedded Solar



Evolution of the Generation Mix

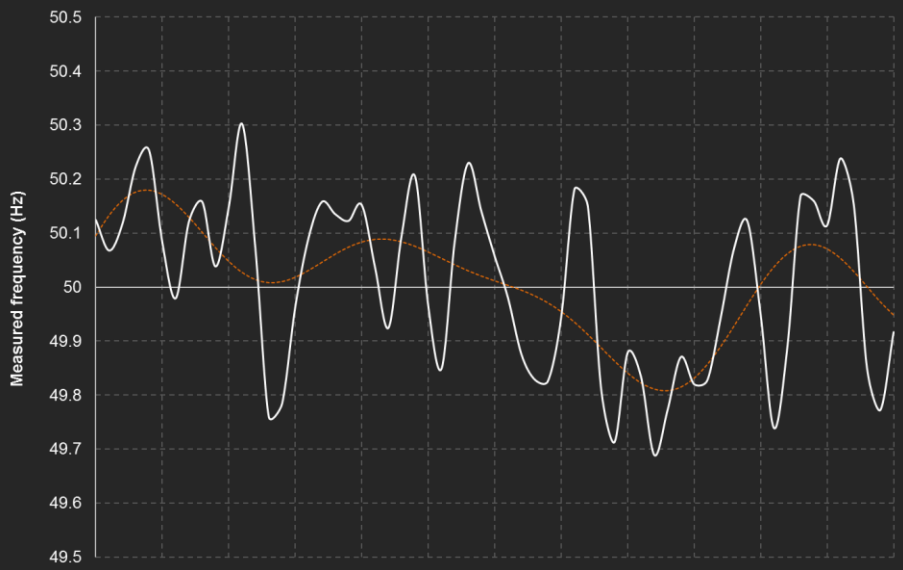


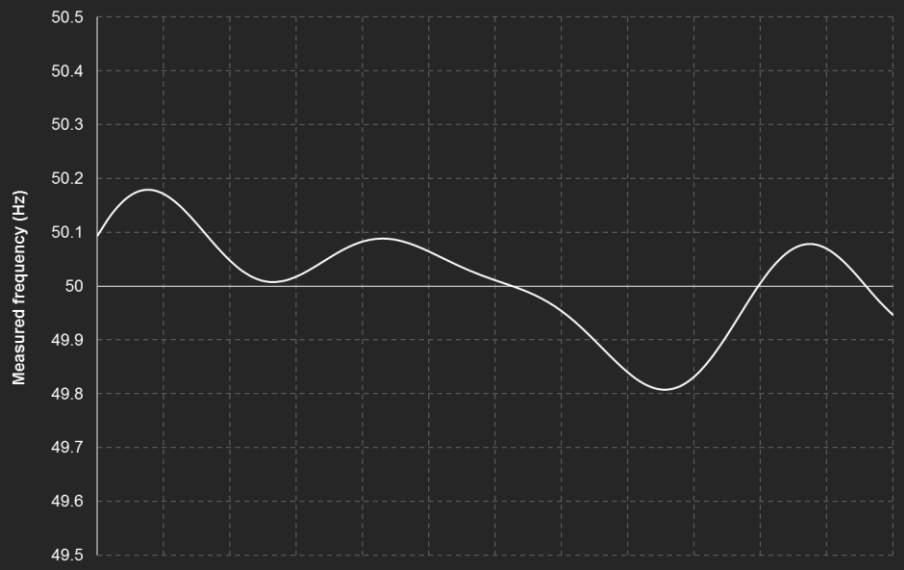
Inertia vs. Demand

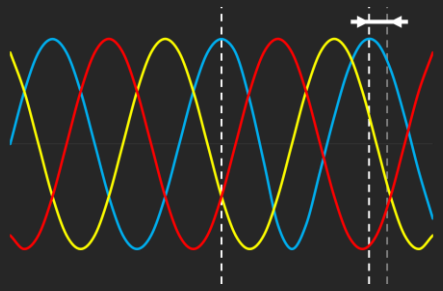


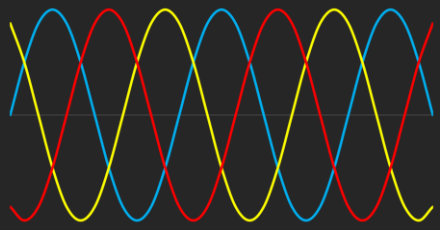
Loss of Mains: Why is it a risk?

Loss of Mains: what's the risk?





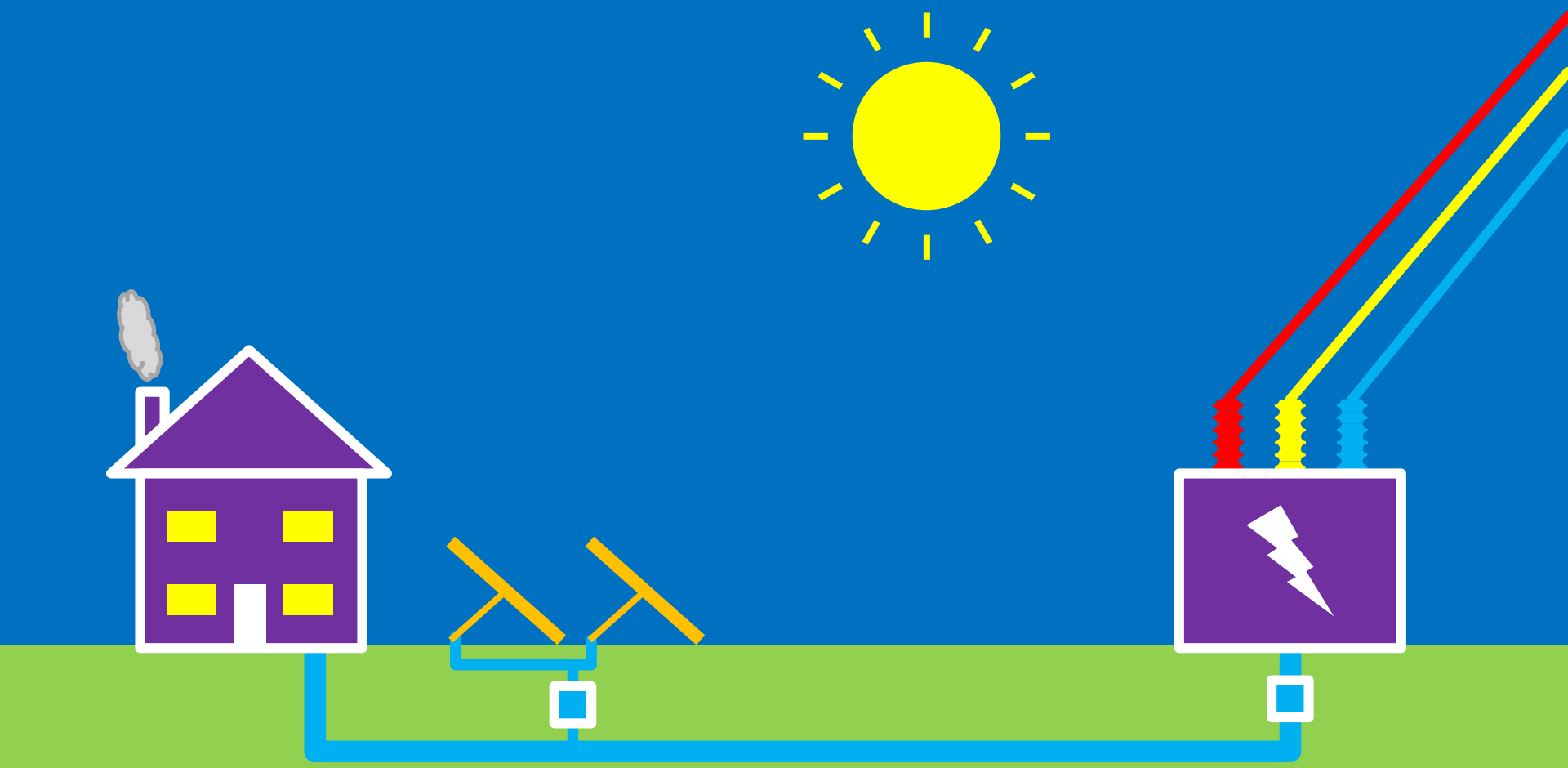




RoCoF high / VS large
→ Small system
→ Islanded

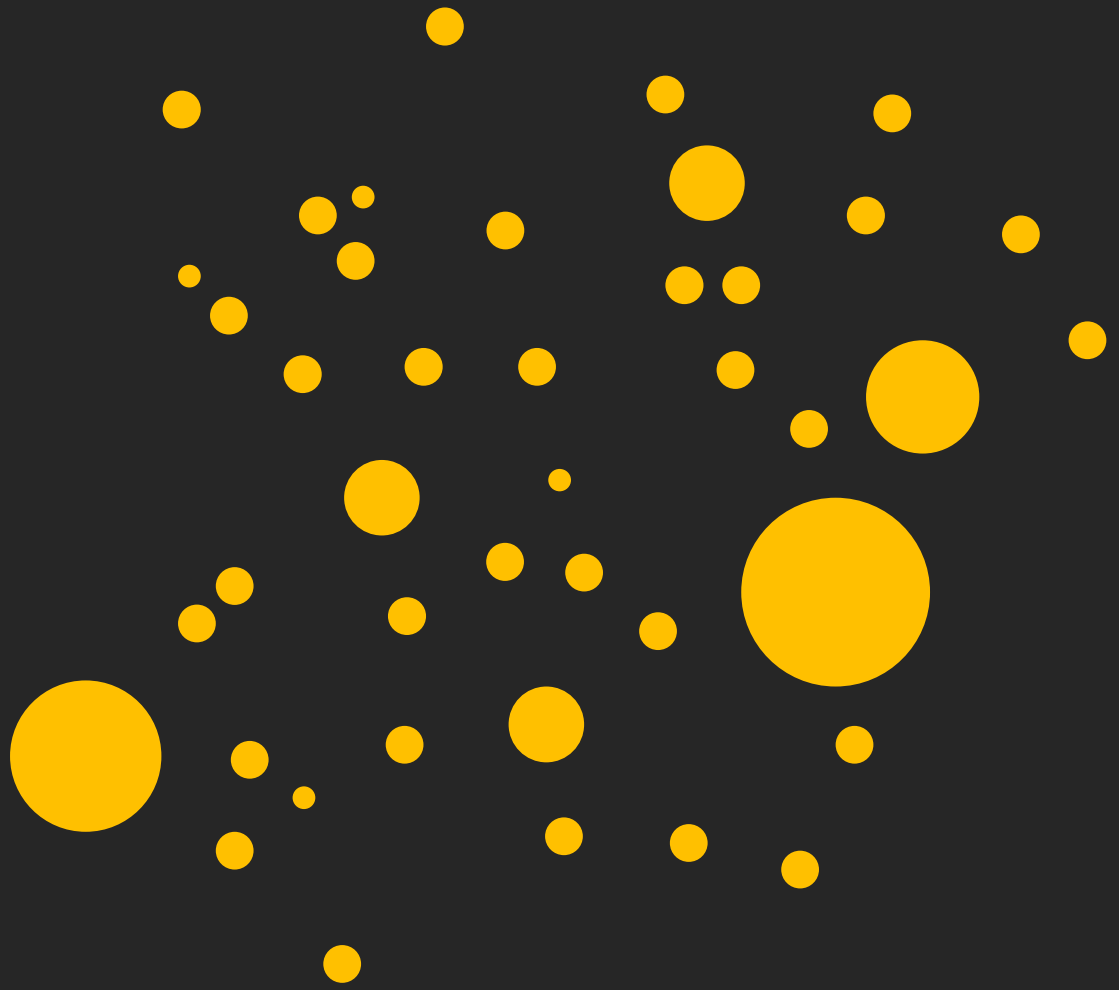
RoCoF low / VS small
→ Large system
→ Connected

Loss of Mains: what's the risk?



RoCoF and VS relays inadvertently react to events on the transmission system

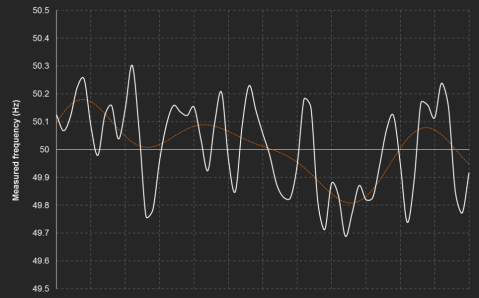
Loss of Mains: what's the risk?

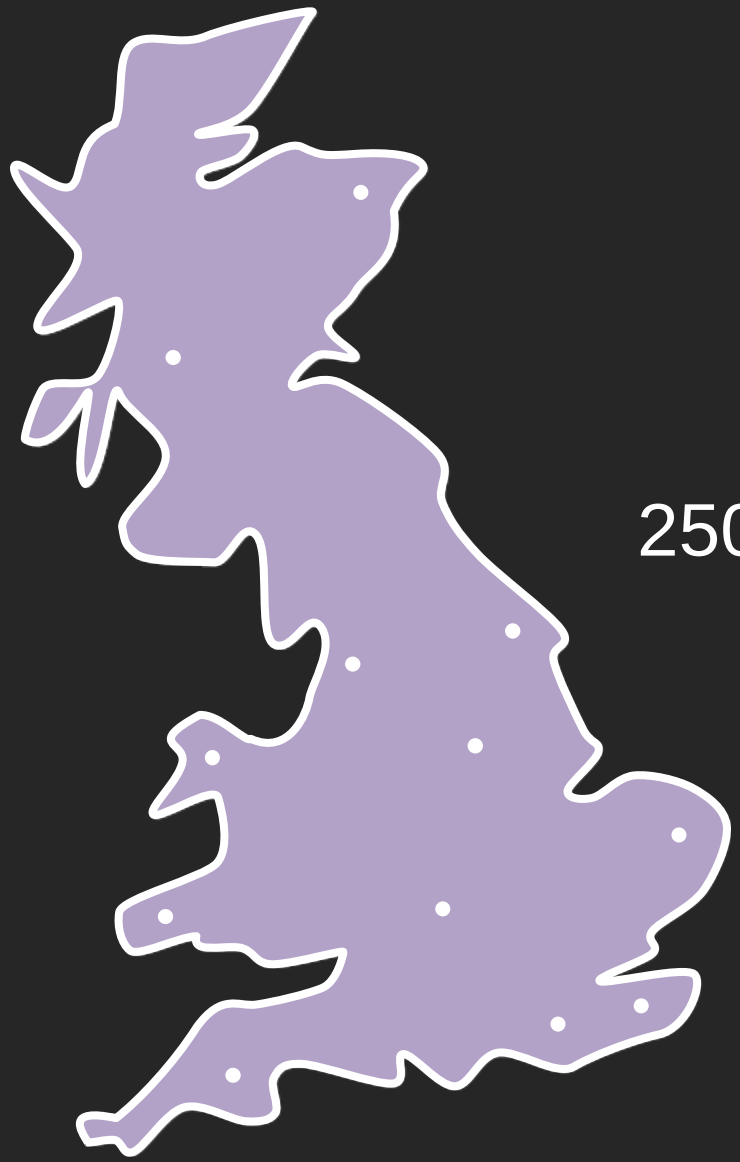


How much could trip?

Loss of Mains risks

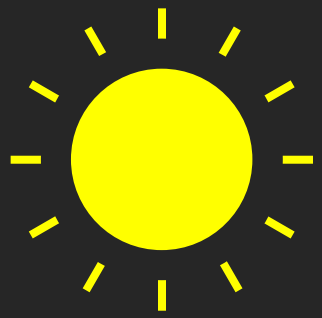
LoM risks: RoCoF



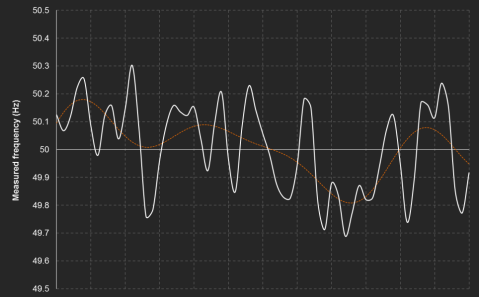


250-750 MW loss

at 0.125Hz/s



LoM risks: RoCoF



250-750 MW loss
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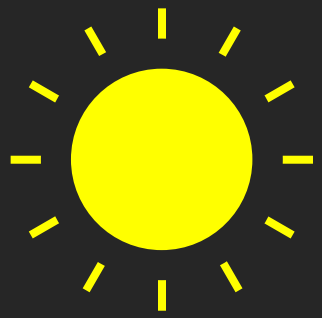
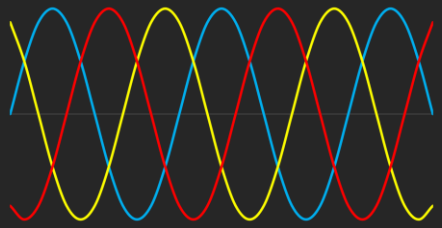


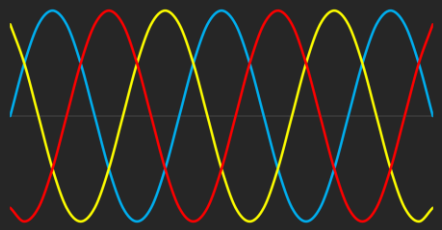
plus a further
200-600 MW
at 0.200Hz/s

LoM risks: Vector Shift

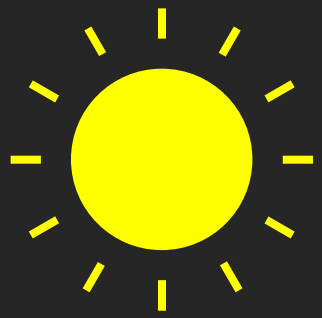


20-200 MW loss

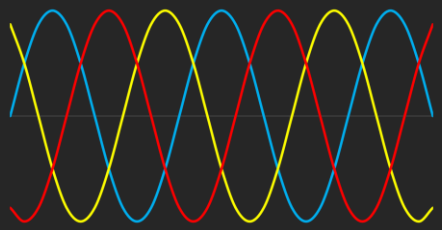
LoM risks: Vector Shift

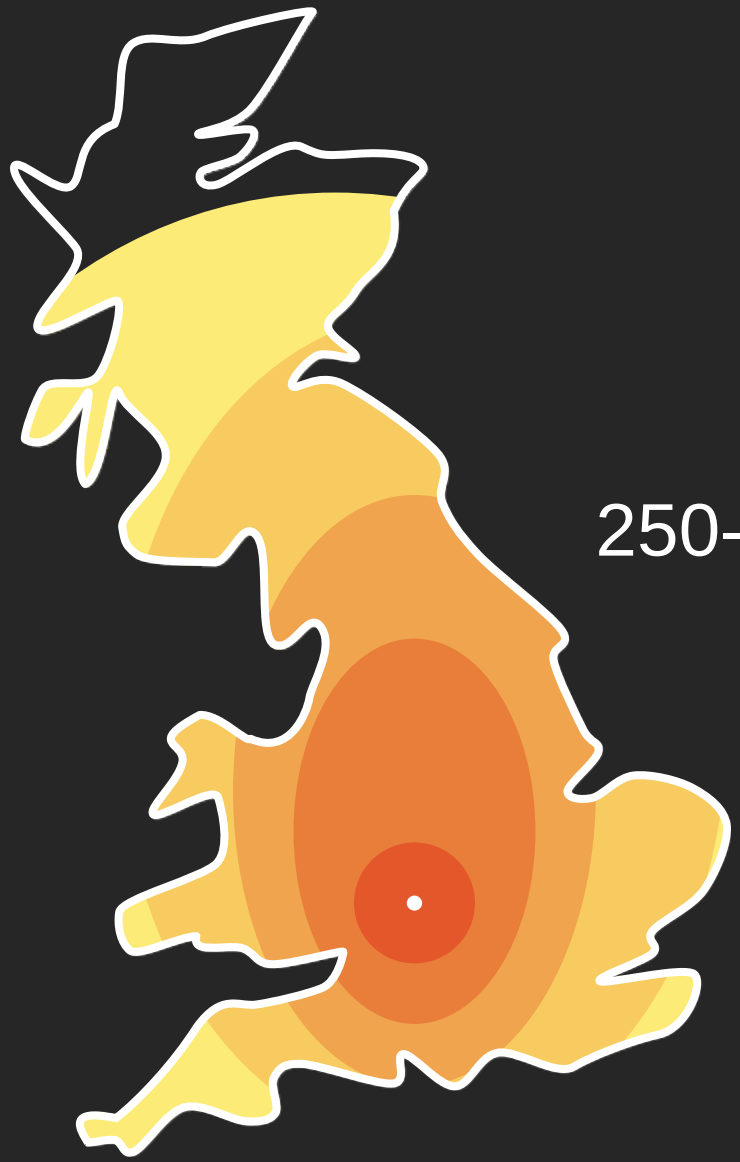


100-600 MW loss

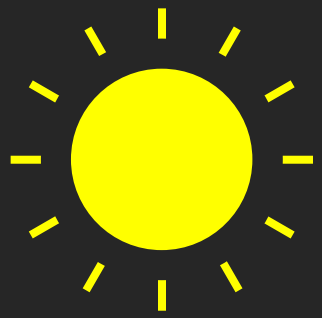


LoM risks: Vector Shift

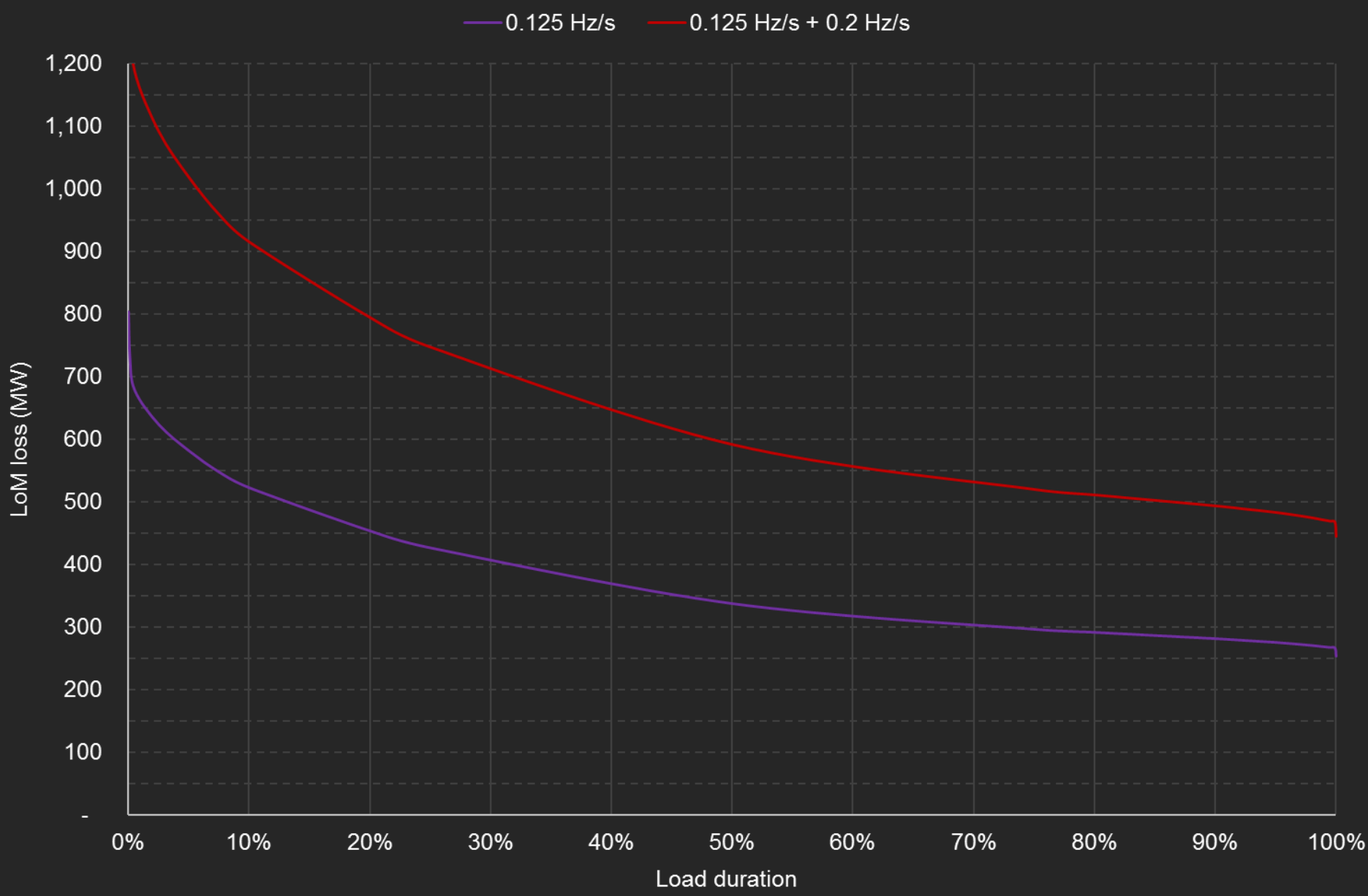




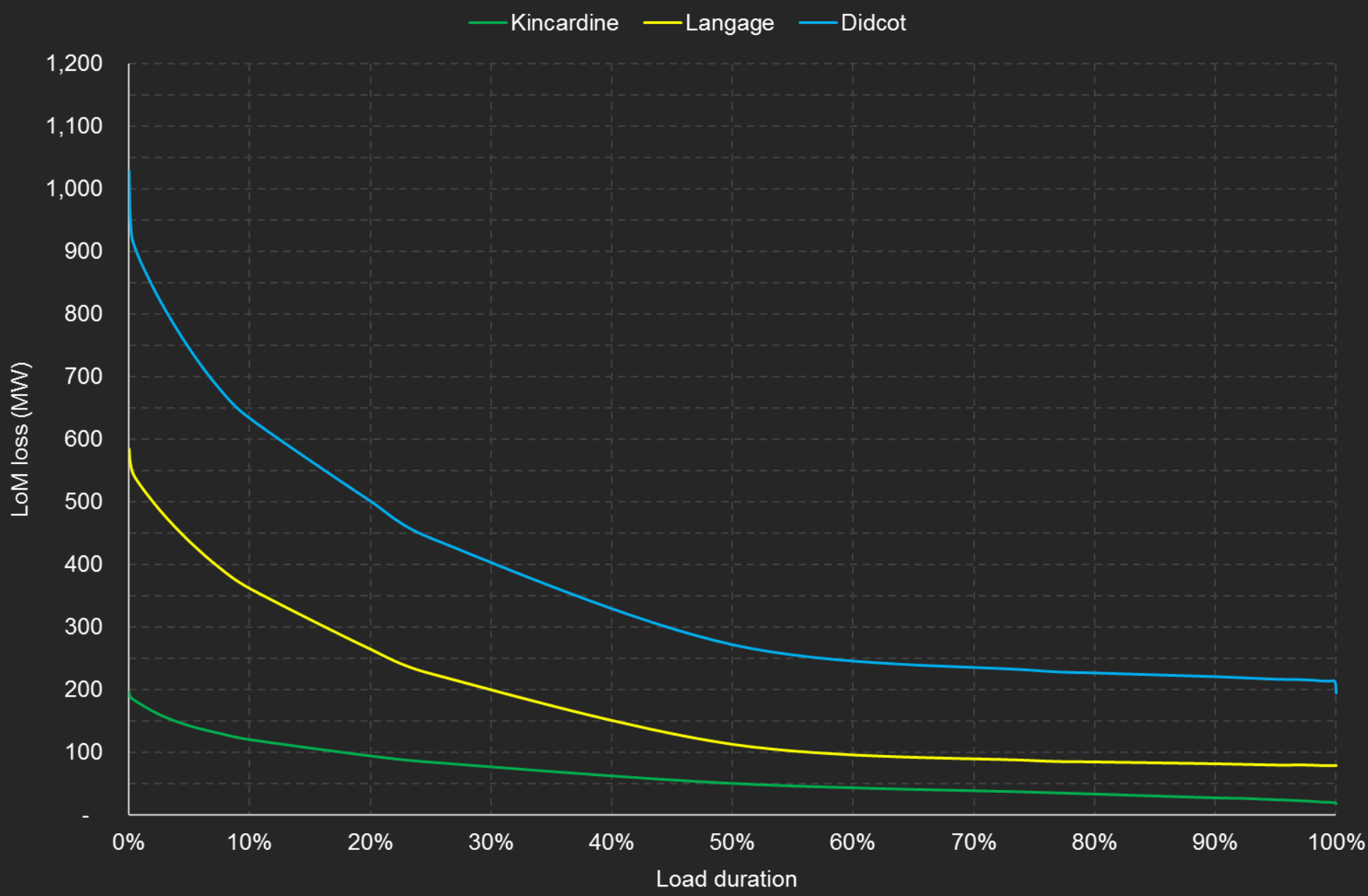
250-1000 MW loss



LoM risks: RoCoF



LoM risks: Vector Shift



LoM risks

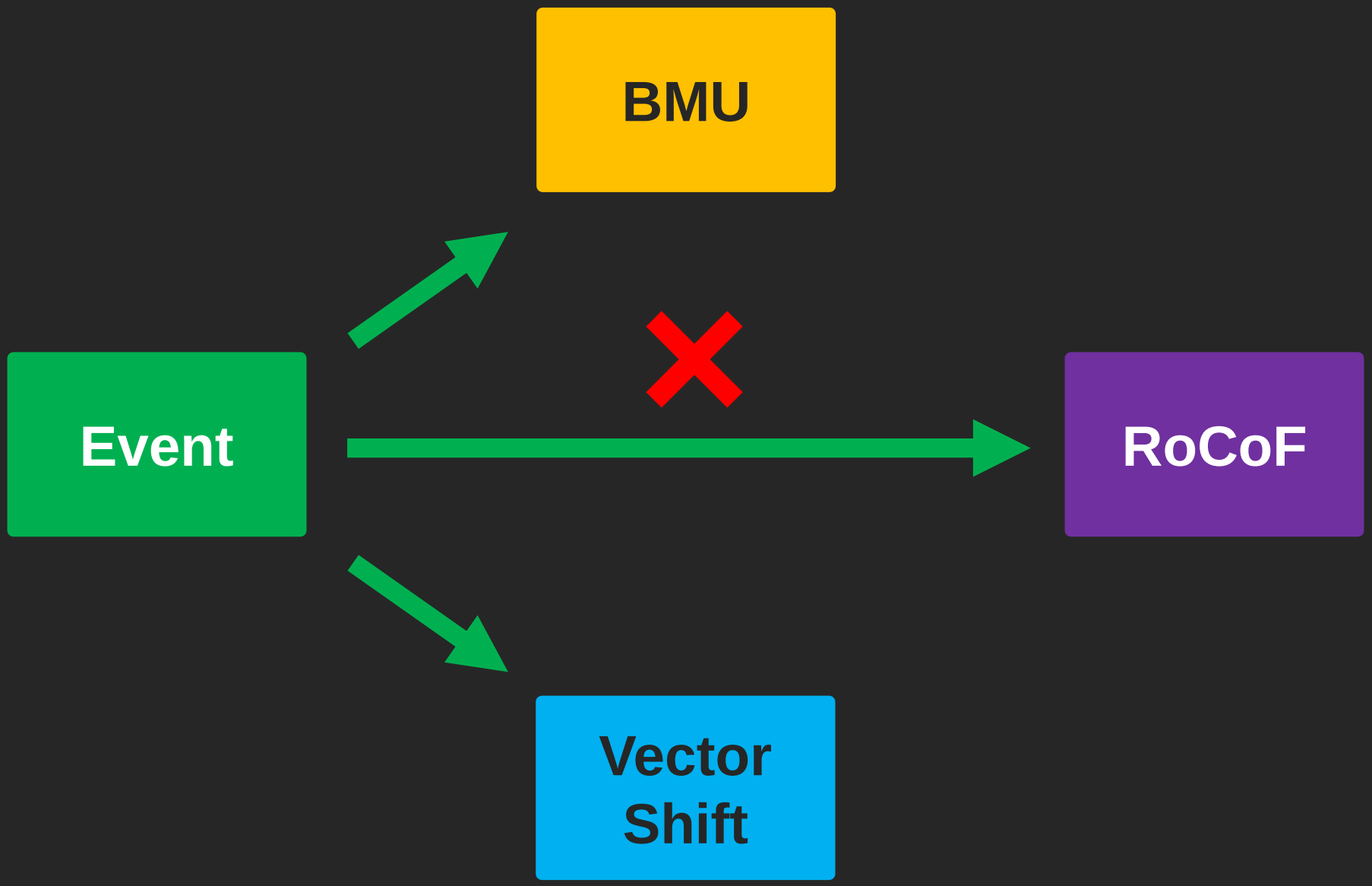
"Depending on the location and nature of a fault that may trigger a VS event, **the SO is potentially unable to protect against such a large loss of infeed**.

An example could be a fault that results in the loss of a major generator or interconnector triggering a further loss of distributed generation due to VS."

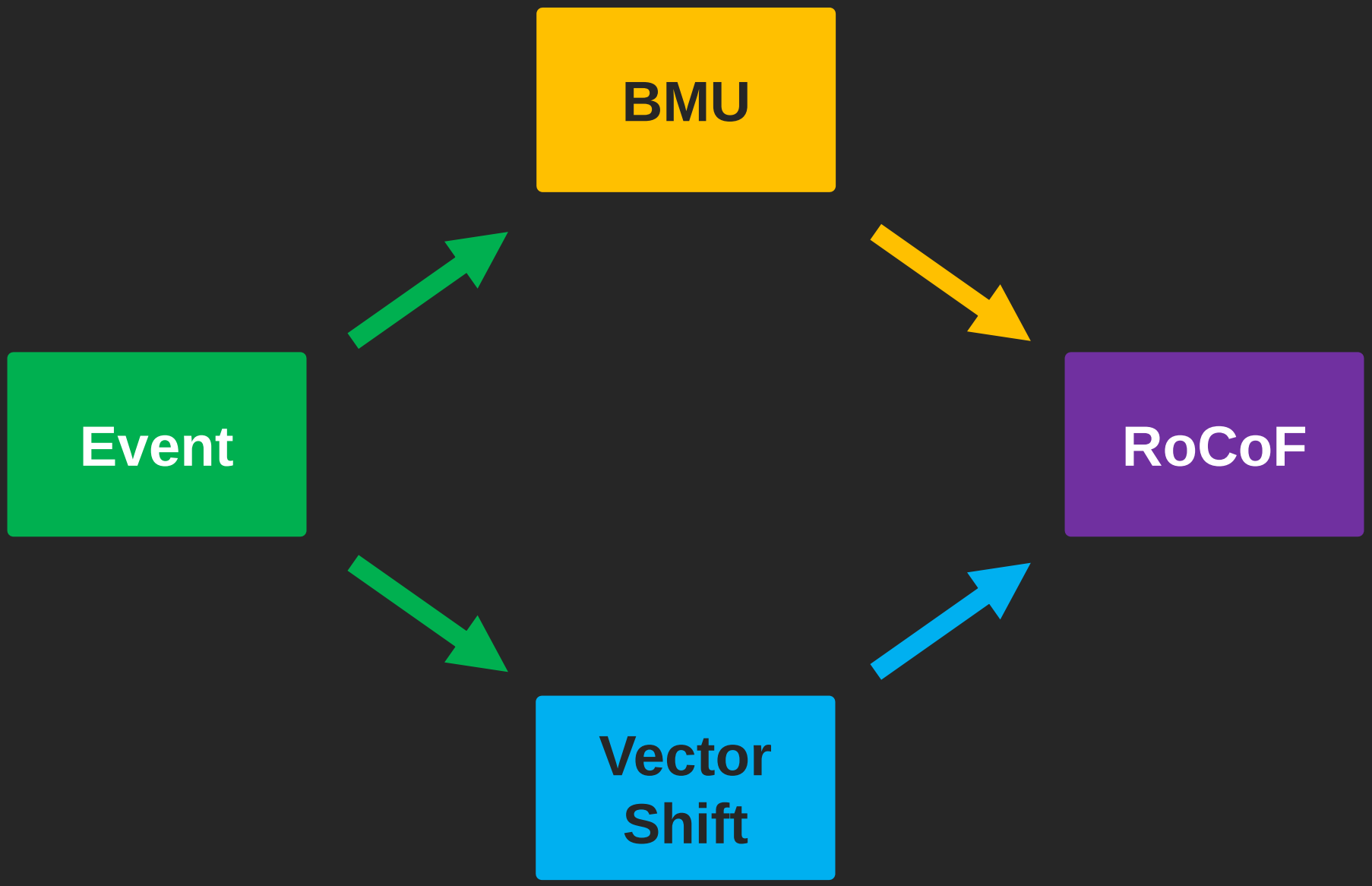
Ofgem Decision: Distribution Code DC0079
Frequency Changes during Large Disturbances and their Impact on the Total System

Combined events

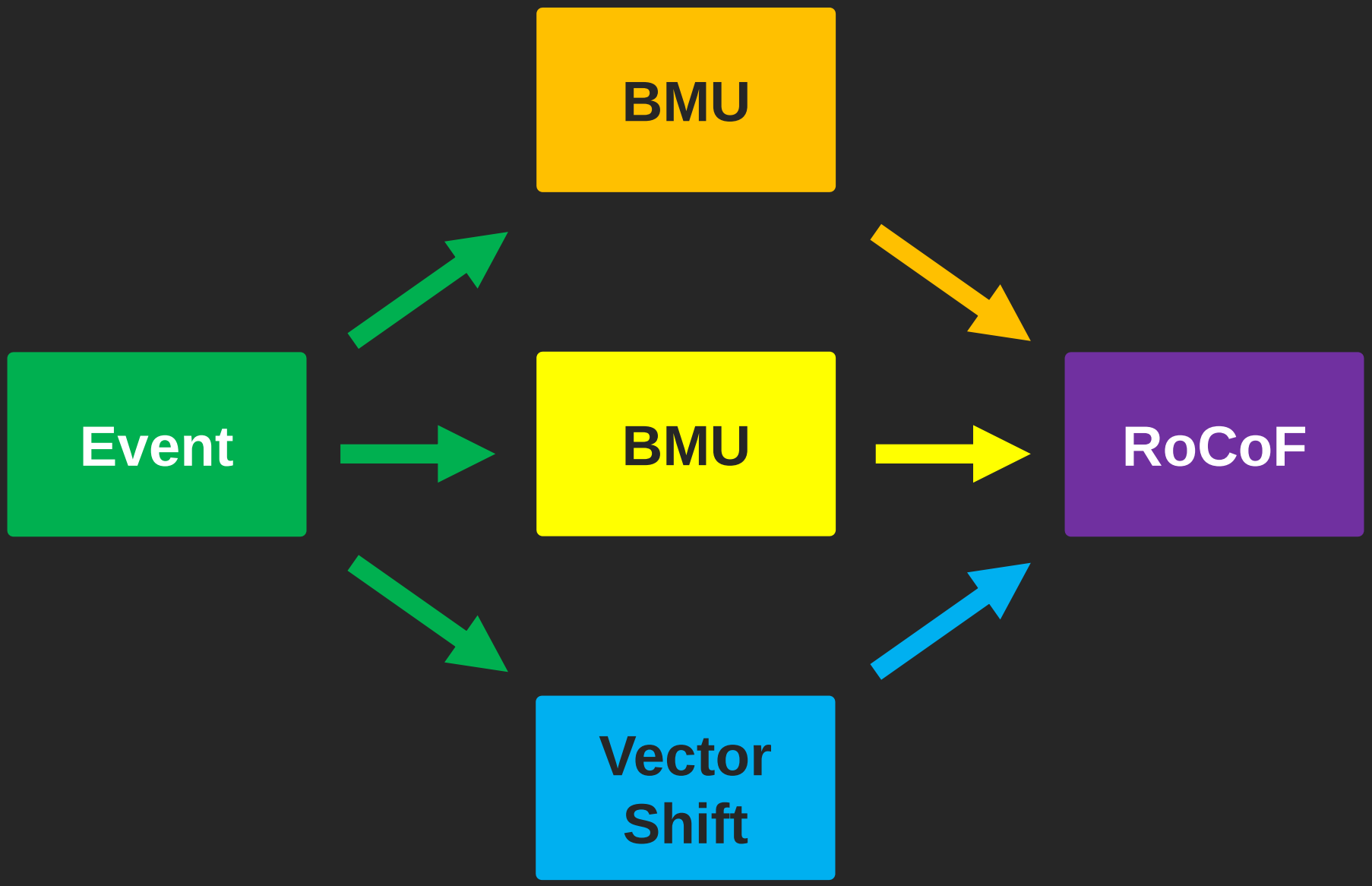
Combined events



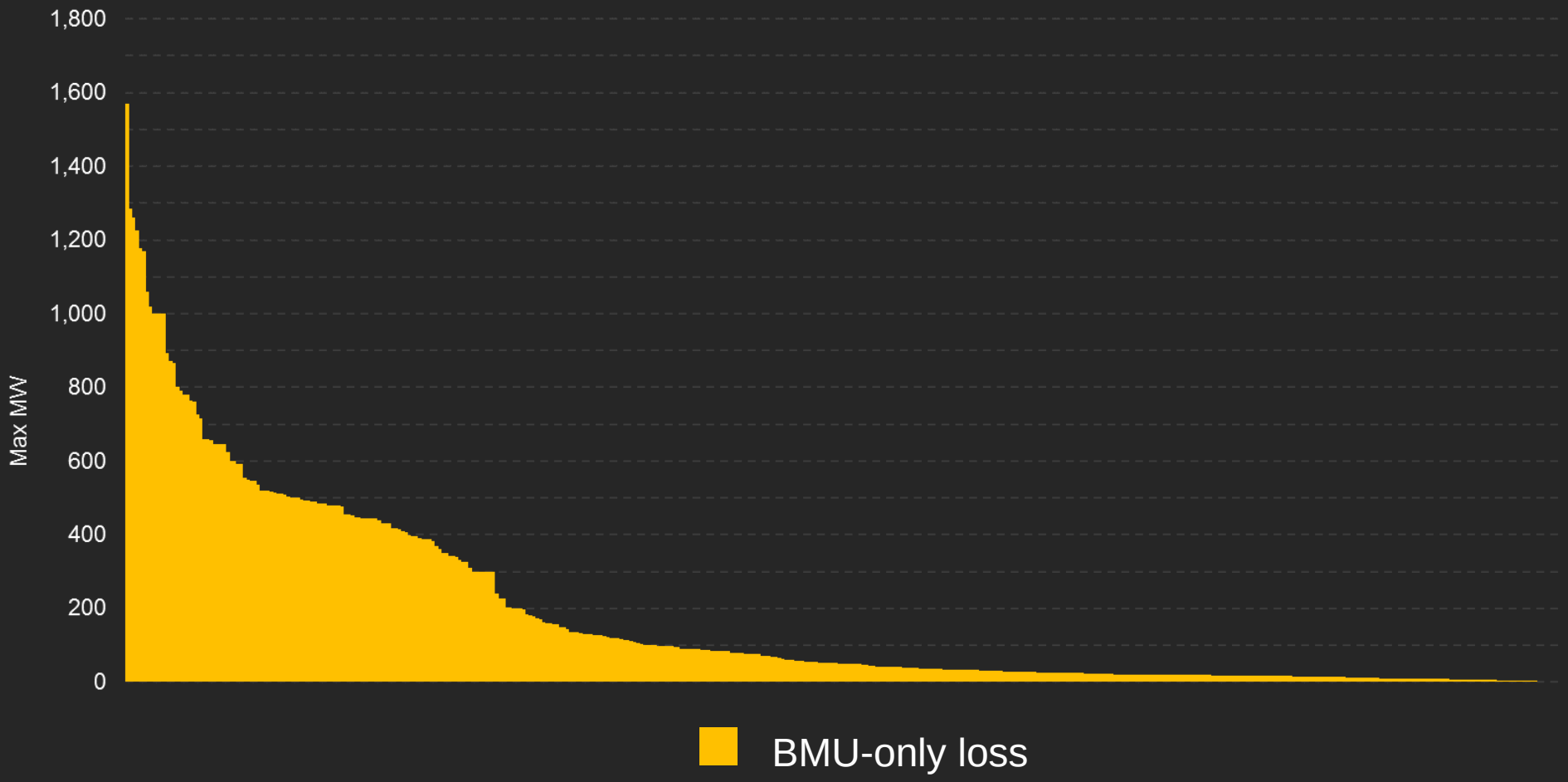
Combined events



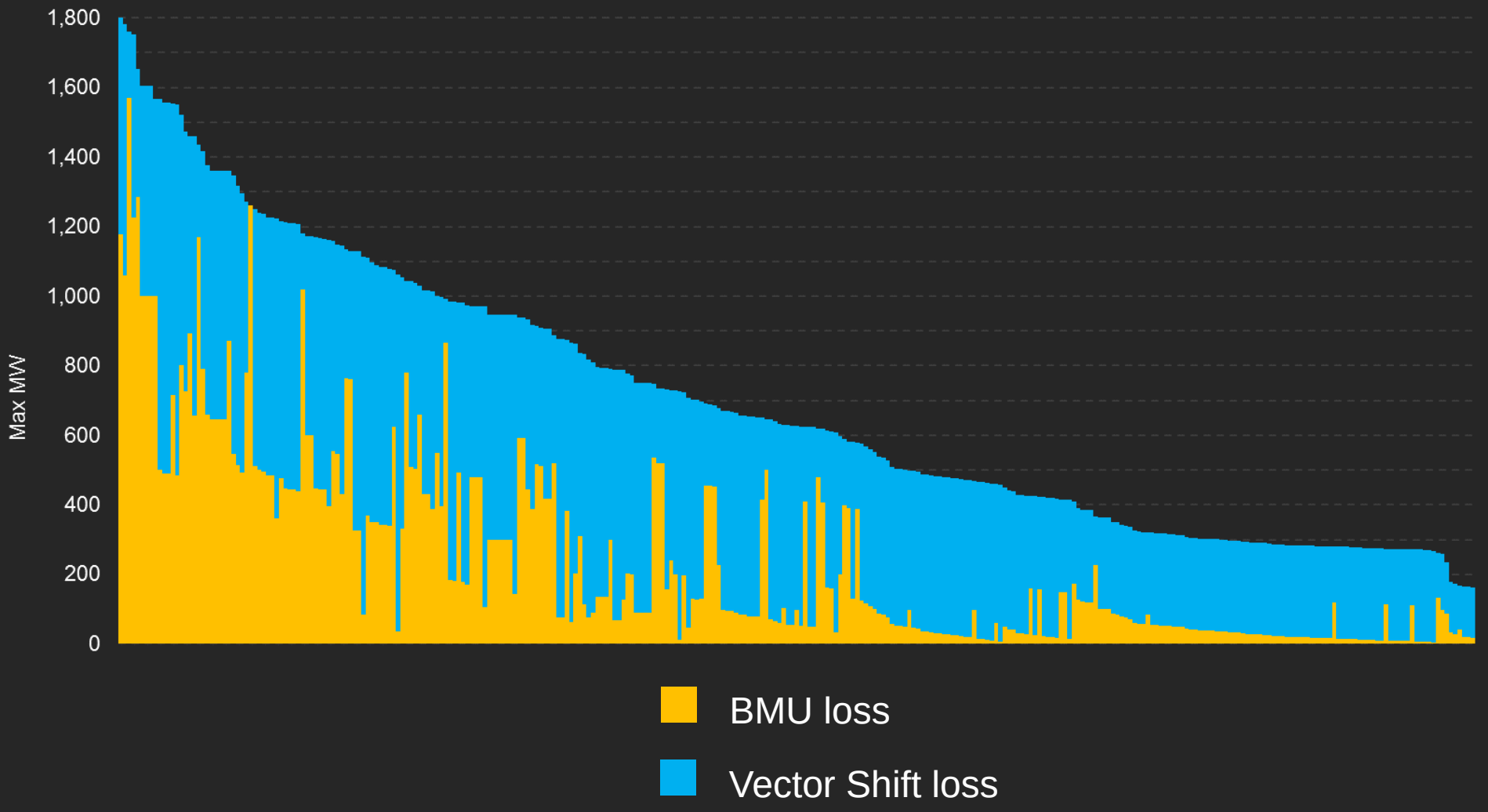
Combined events



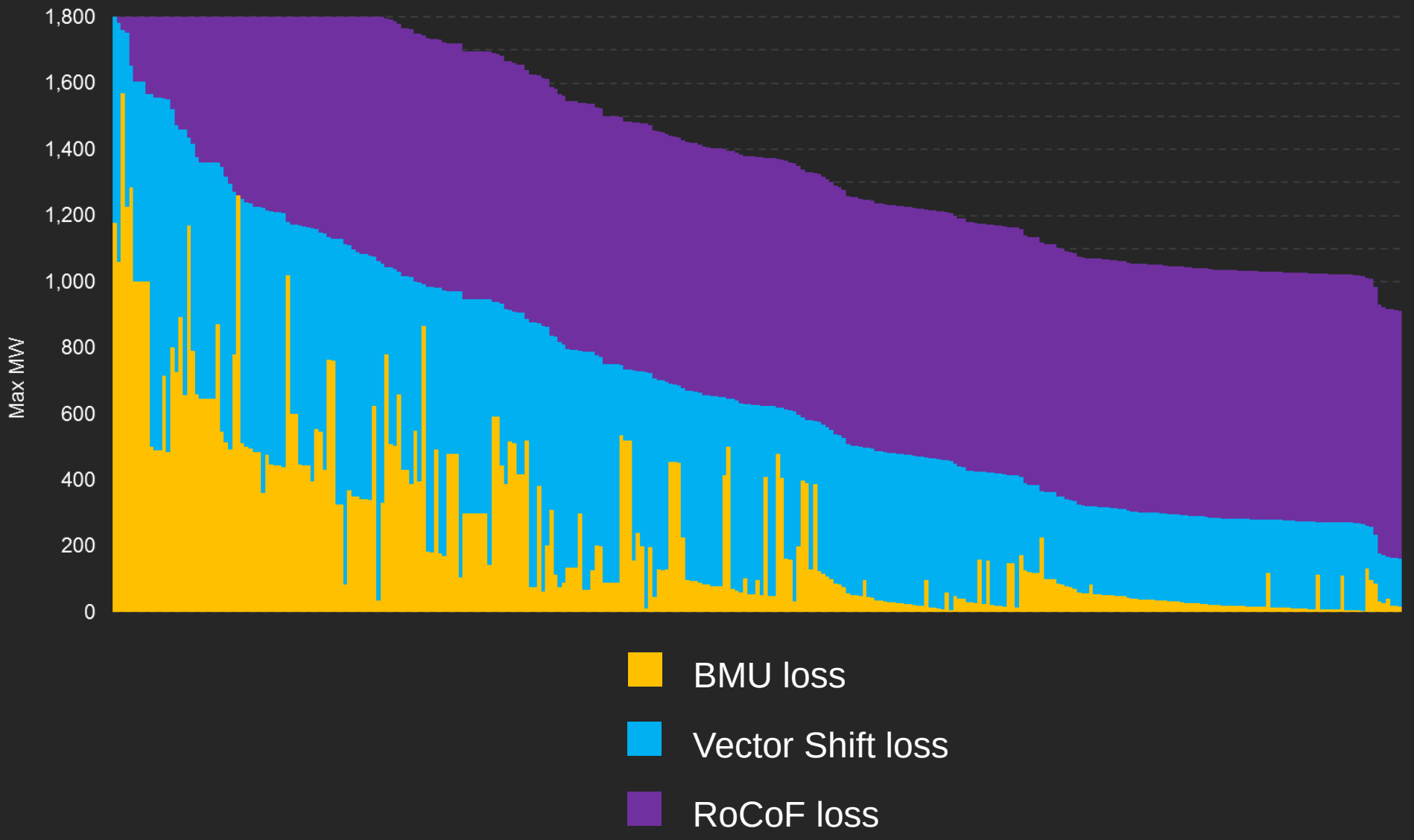
Combined events



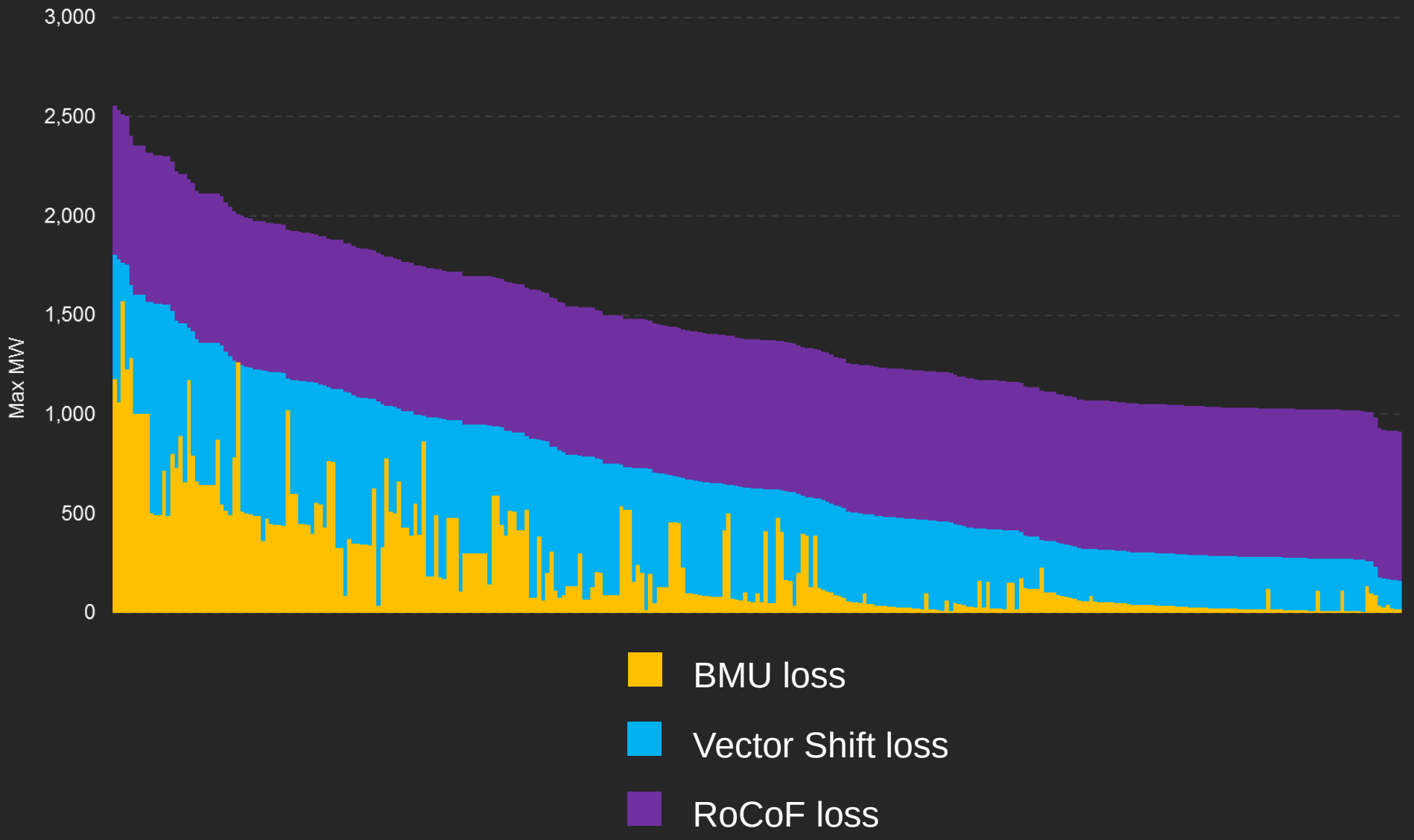
Combined events



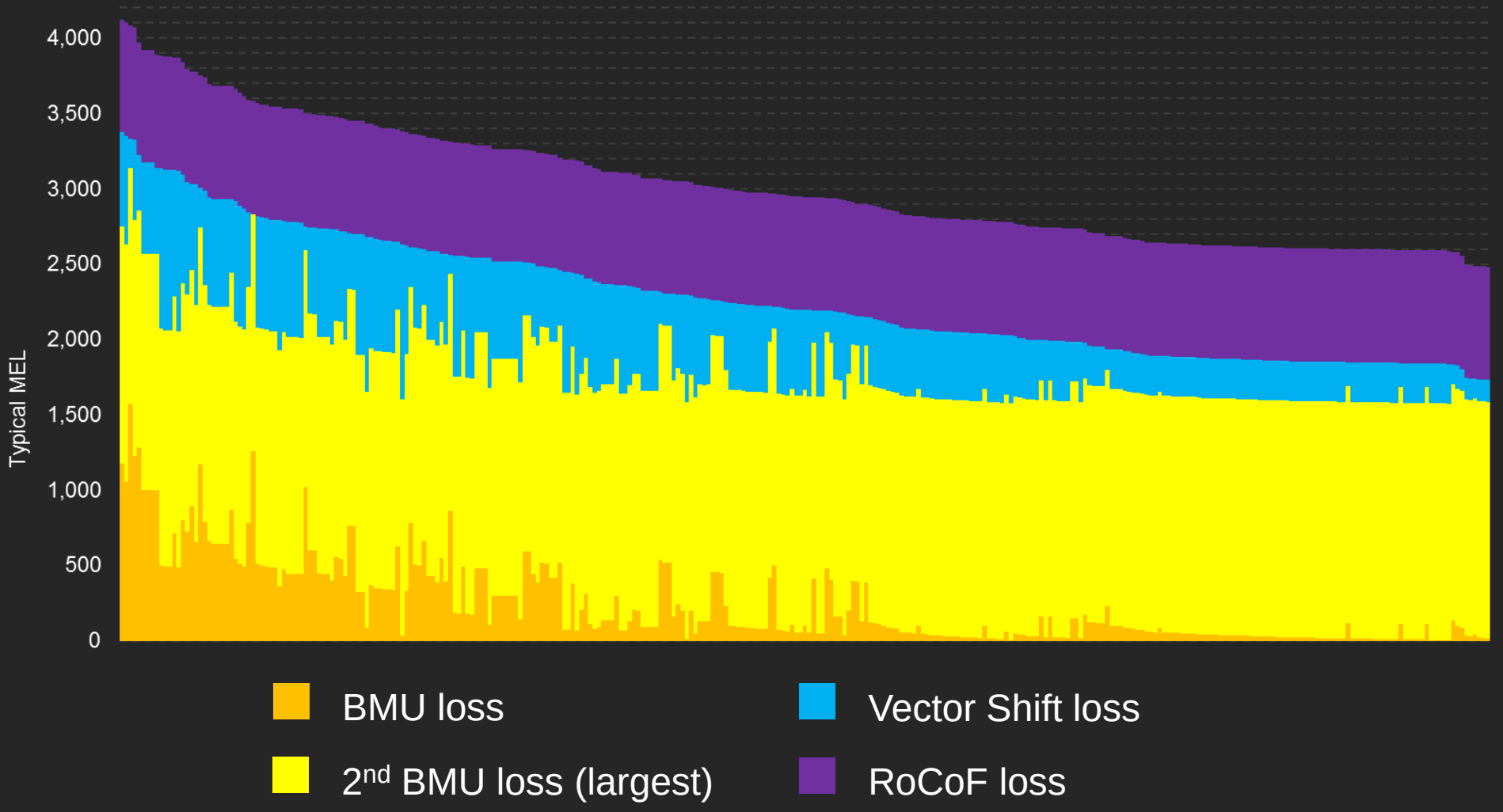
Combined events



Combined events



Combined events



Question 1

a. What is considered “infrequent”?

b. What happens if you go outside the limits of 50.0Hz ± 1%?

c. What could cause you to go outside the limits, and by how much?

d. How often could that happen?

- There is a wide range of loss sizes
- They vary with:
  - the type of fault — *BMU? VS? RoCoF?*
  - the system conditions — *demand, inertia, RoCoF / VS output*
  - the time of year and time of day — *BMU running pattern*
  - mitigations in place — *response, inertia etc.*
- In the absolute worst-case, generation losses could be very big
  but….
  the likelihood of that precise combination of events happening is low

Question 1: Risks

a. What is considered “infrequent”?

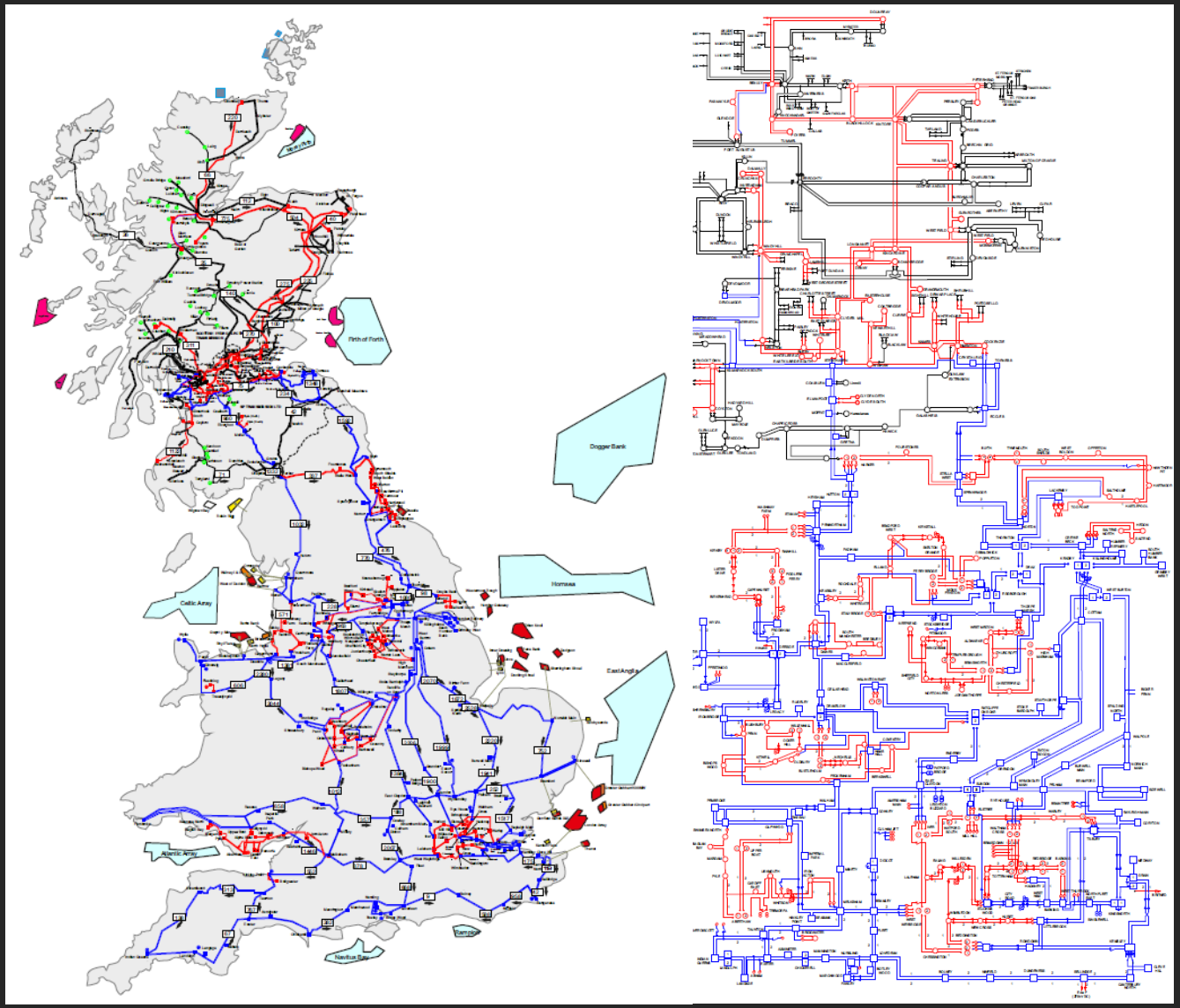
b. What happens if you go outside the limits of 50.0Hz ± 1%?

c. What could cause you to go outside the limits, and by how much?

d. How often could that happen?

How likely are events?

Event likelihoods



400 / 275kV
Transmission voltages

22,300 km
Overhead Line

900 km
Underground Cables

1305
sites

190,000
sets of maintenance

~88,000
pylons

Event likelihoods

2 double circuit faults
105 single circuit faults

10 transformer faults

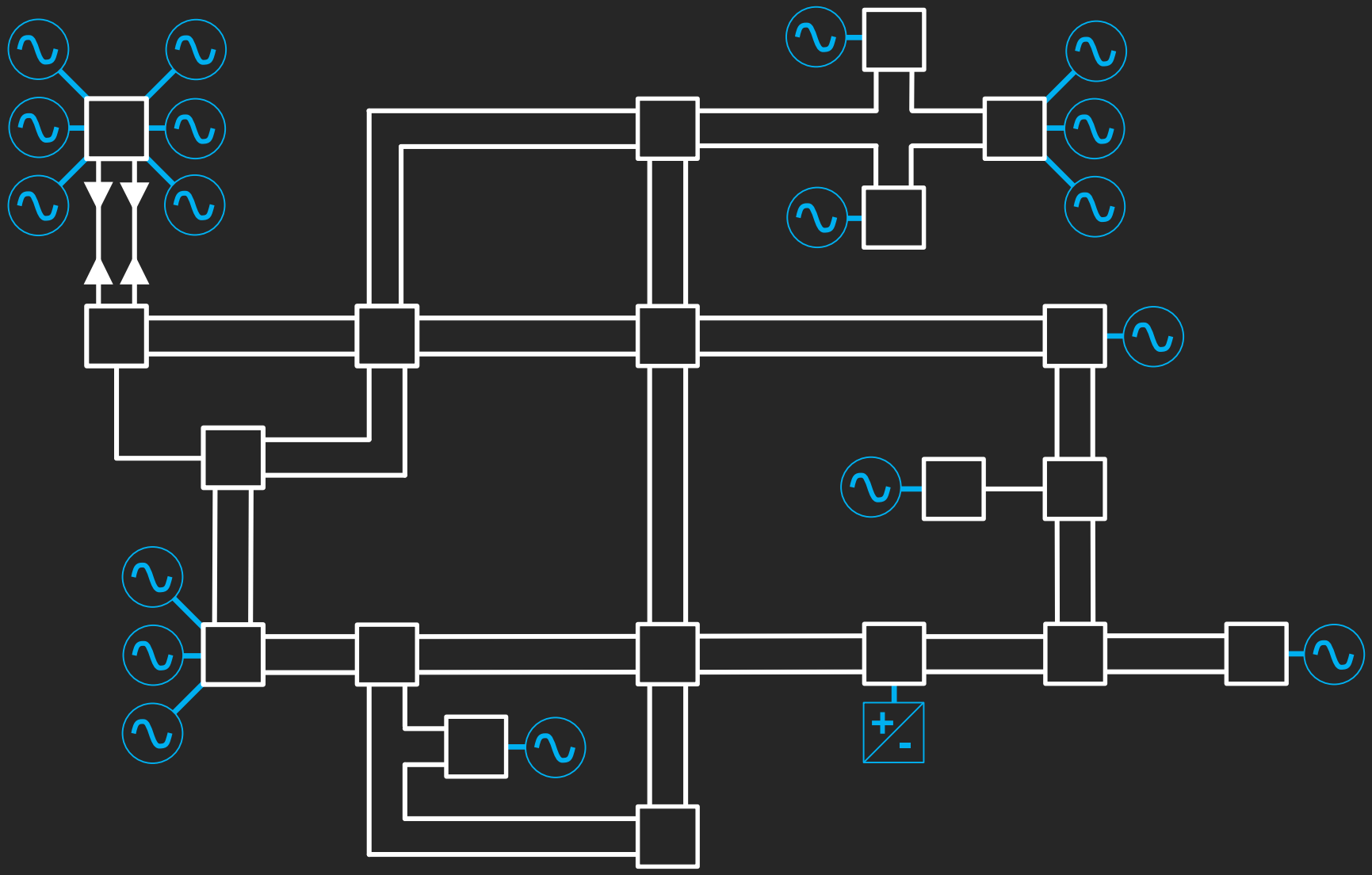
2000 protection / comms failures

4 busbar faults

5 cable faults

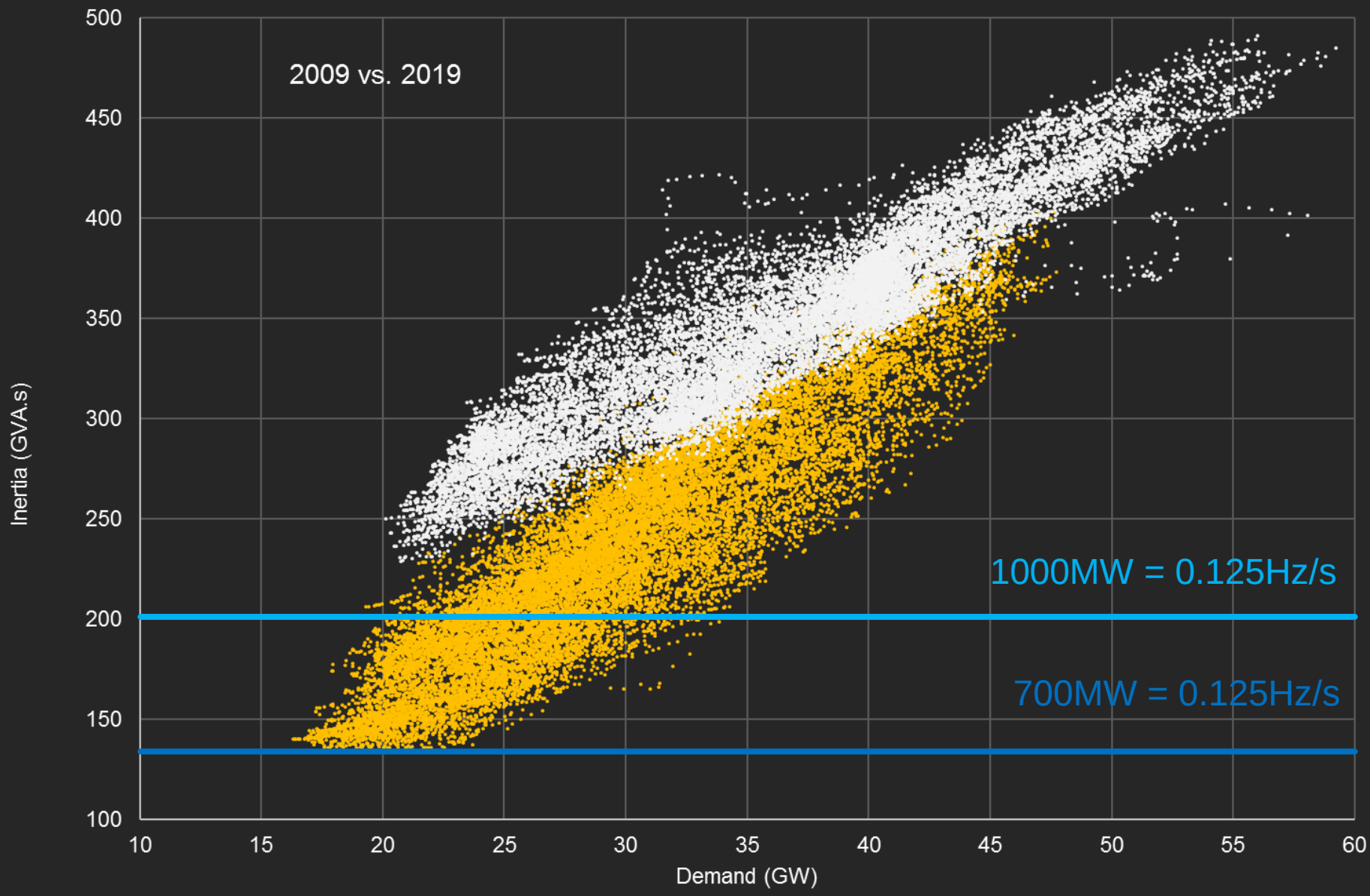
21 circuit breaker faults

Event likelihoods



BMU | Bar / MC | Single | Double | Other

Event likelihoods



Question 1: Risks

a. What is considered “infrequent”?

b. What happens if you go outside the limits of 50.0Hz ± 1%?

c. What could cause you to go outside the limits, and by how much?

d. How often could that happen?

- Very dependent on the type of event
- For an individual risk (regardless of severity of frequency deviation):

• BMUs	a few times per year
• Bar / Mesh corner	1-in-200 years
• Single circuit OHL	1-in-20 years
• Single circuit cable	1-in-75 years
• Double circuit (short)	1-in-40 years
• Double circuit (long)	1-in-2000 years
• Other	very varied

- Very dependent on the system conditions at the time

Key Questions

Key questions

1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

- How often frequency goes outside the limits of 50.0Hz ± 1%
- How often the LFDD scheme is activated

- There are a wide variety of events that could cause these conditions

- These events have:
  - different causes
  - different sizes
  - different likelihoods
  - different consequences

Key questions

1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

Structure

Frequency	Risks	Control	Proposal
Primary legislation	Transmission-connected	Mitigating risks	Frequency Risk & Control Report
SQSS implementation	Loss of Mains	Interactions and complexity	
Real-life impact	Combined events	Projects Pipeline	
	Likelihood of events		

Control

Mitigating events

Mitigating events

Reduce loss size

Hold more response

Increase inertia

Reduce LoM capacity at risk

Mitigating events: BMU-only

Reduce loss size	✓	bids on large units (BOA, trading)
Hold more response	✓	feasible with current products
Increase inertia	✓	synchronise high inertia units
Reduce LoM capacity at risk	–	n/a

Mitigating events: BMU + RoCoF

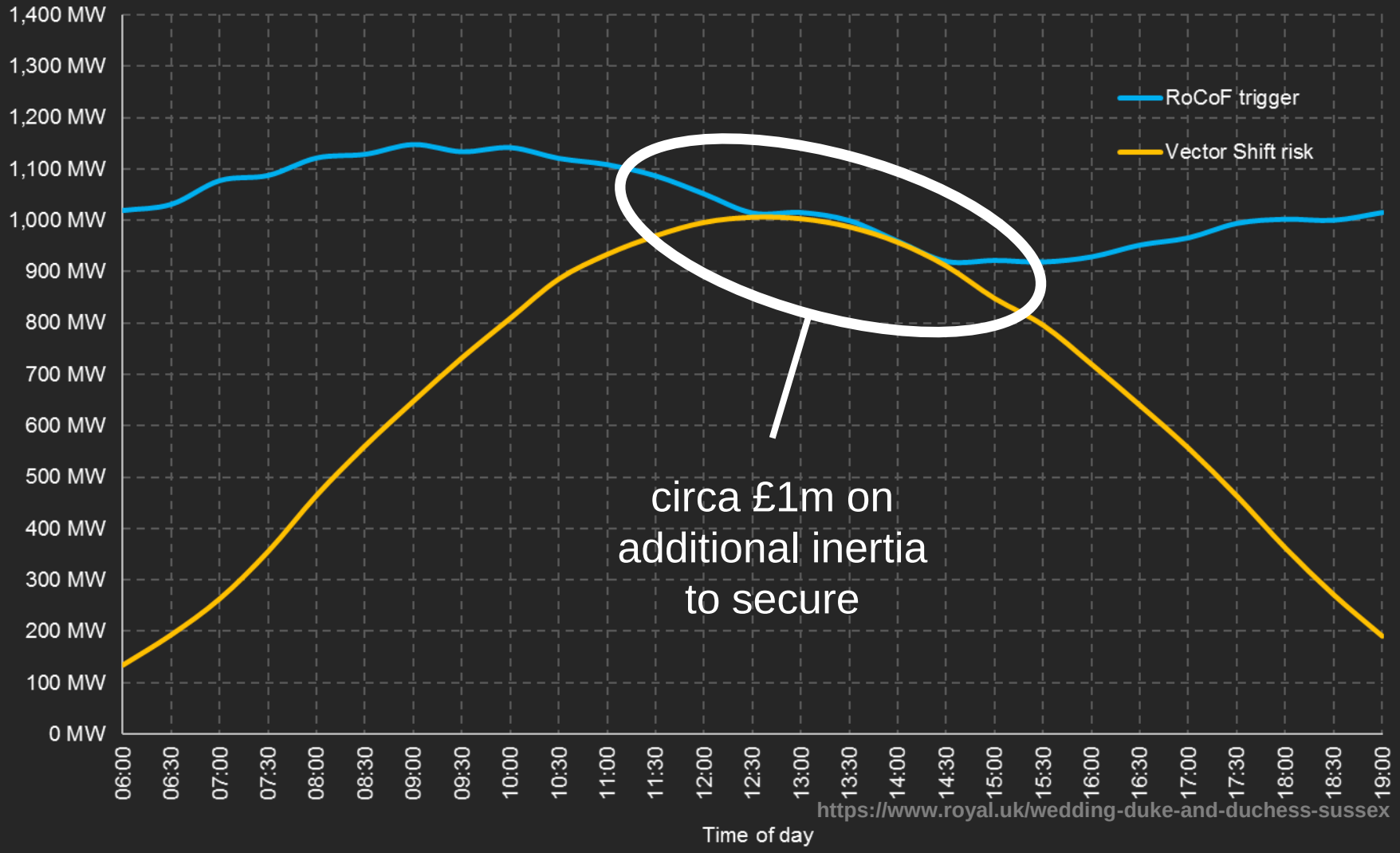
Reduce loss size	✓	bids on large units (BOA, trading)
Hold more response	✗	not enough to secure loss size
Increase inertia	✓	synchronise high inertia units
Reduce LoM capacity at risk	✓	D-Code mod for remaining capacity Accelerated Loss of Mains Change Programme (ALoMCP)

Mitigating events: Vector Shift + RoCoF

Reduce loss size	✗	no real-time control of VS
Hold more response	✗	not enough to secure loss size
Increase inertia	✗	not always feasible
Reduce LoM capacity at risk	✓	D-Code mod for remaining capacity Accelerated Loss of Mains Change Programme (ALoMCP)

Mitigating events: Vector Shift + RoCoF

Sat 19 May 2018: Royal Wedding



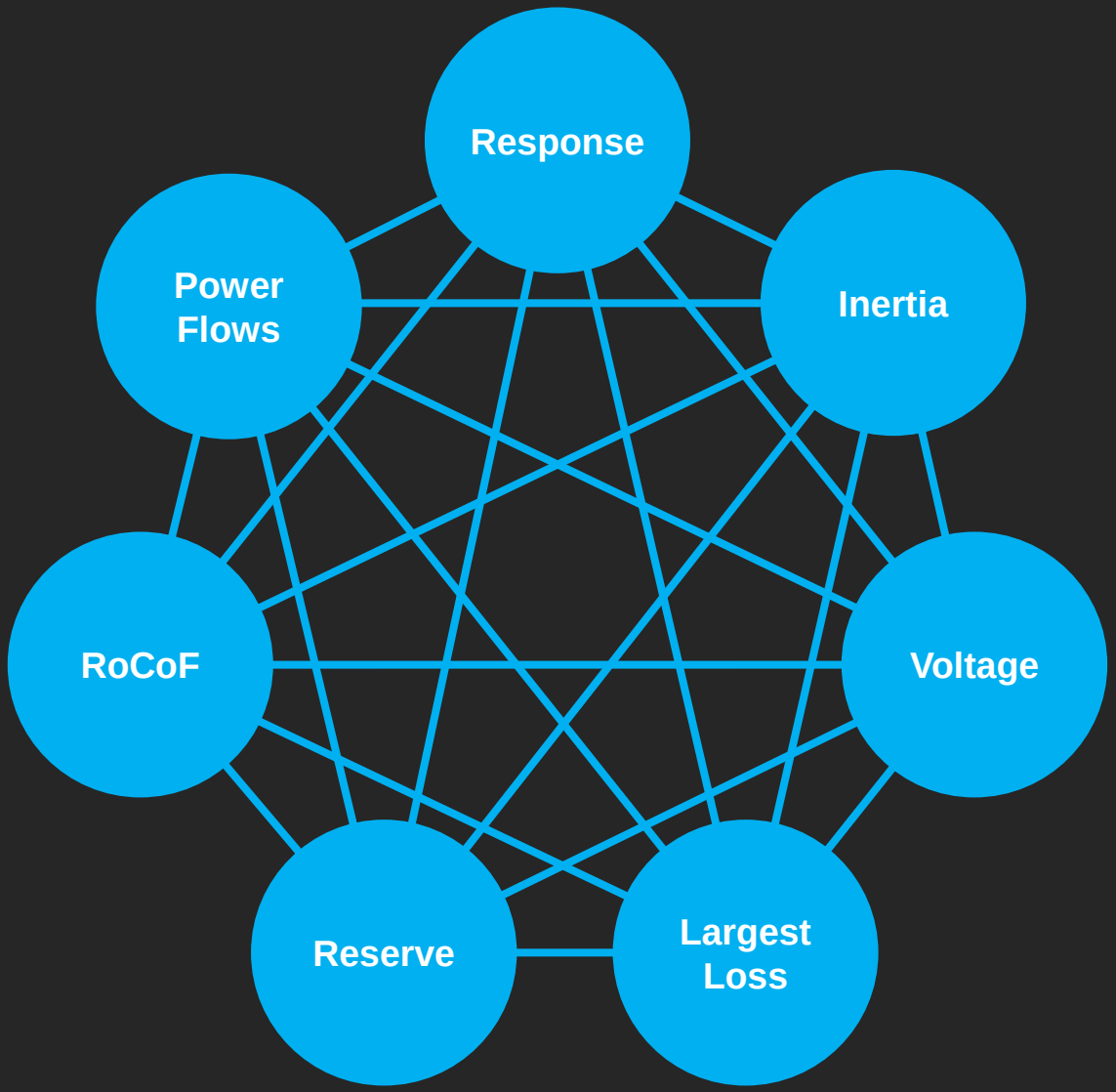
Mitigating events: Vector Shift + RoCoF

Reduce loss size	✗	no real-time control
Hold more response	✗	not enough to secure loss size
Increase inertia	✗	not always feasible
Reduce LoM capacity at risk	✓	D-Code mod for remaining capacity Accelerated Loss of Mains Change Programme (ALoMCP)

Also applies to BMU + Vector Shift + RoCoF

Interactions & complexities

“The fundamental interconnectedness of all things”



- Interactions are key
- Exacerbated by:
  - Low inertia
  - Low demand
- New tools
- More actions

Key questions

1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

- Look at the cost of
  - Taking bids to reduce loss size
  - Holding response and reserve
  - Increasing inertia
  - Reducing Loss of Mains capacity
- Do this for different scenarios and assumptions
  - BMU, VS and RoCoF loss sizes
  - System conditions — demand, inertia, …
  - Ancillary service services — quantity, price…
- Assess cost for individual events, and as a whole system (as some actions solve multiple issues)

What’s in the pipeline?

What's in the pipeline?

Zero-carbon	Response	Inertia	Loss of Mains
Lower inertia	Dynamic Containment	Stability Pathfinder (Ph 1)	ALoMCP
Changing demand	Dynamic Moderation	Stability Pathfinder (Ph 2)	
New loss risks	Dynamic Regulation	Stability Market?	
	Other products		

Structure

Frequency	Risks	Control	Proposal
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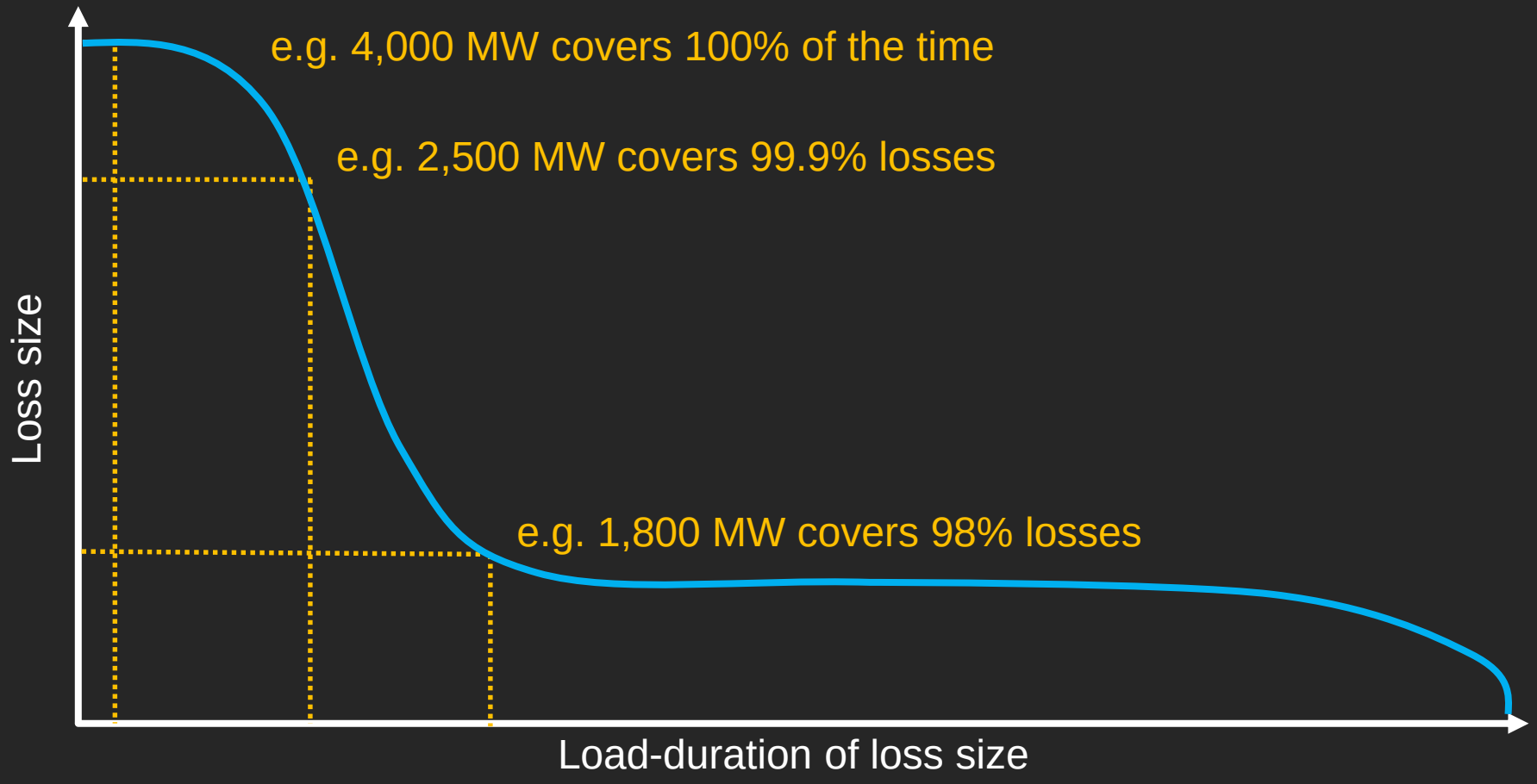
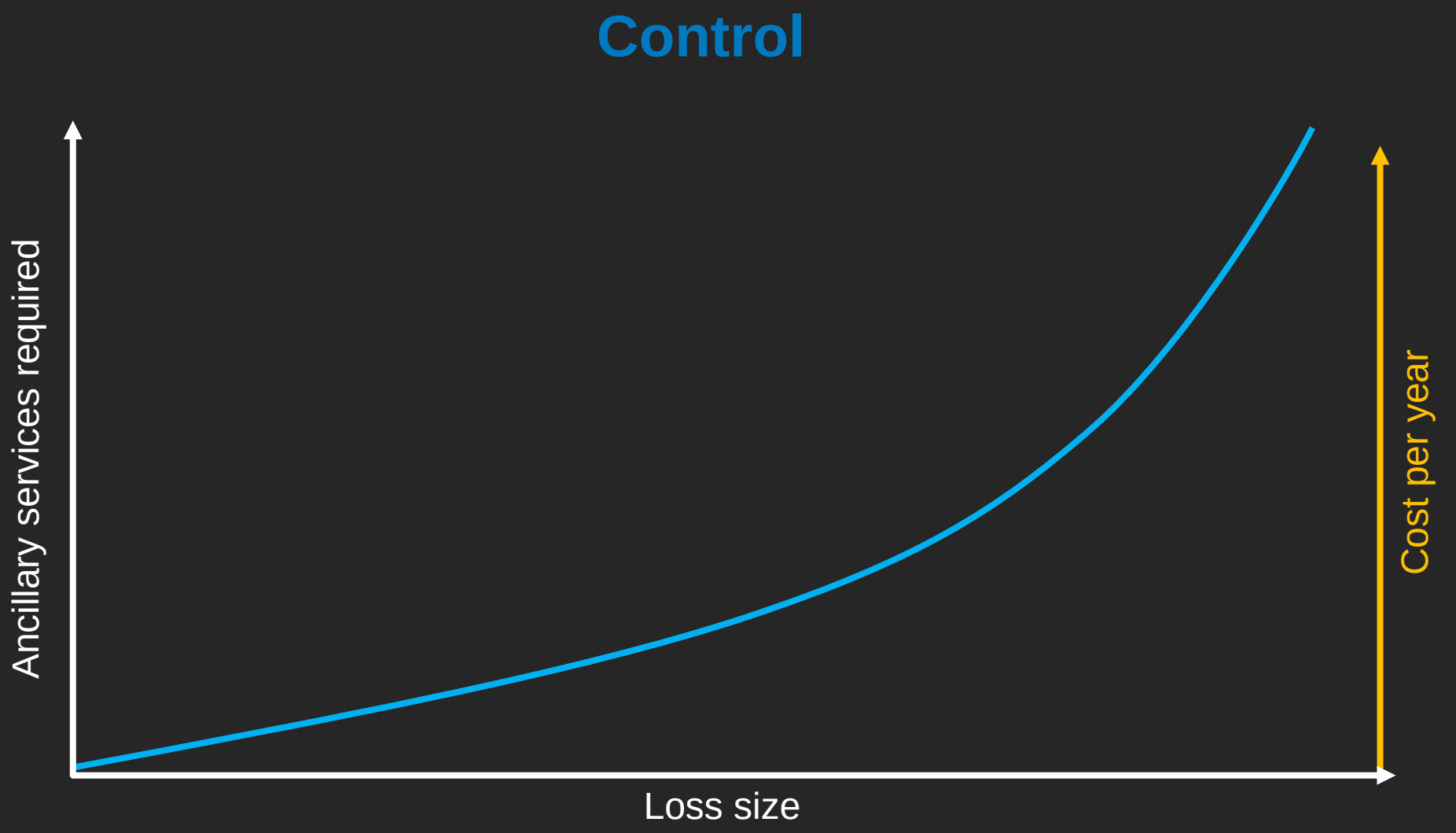
Frequency Risk and Control Report

Key questions

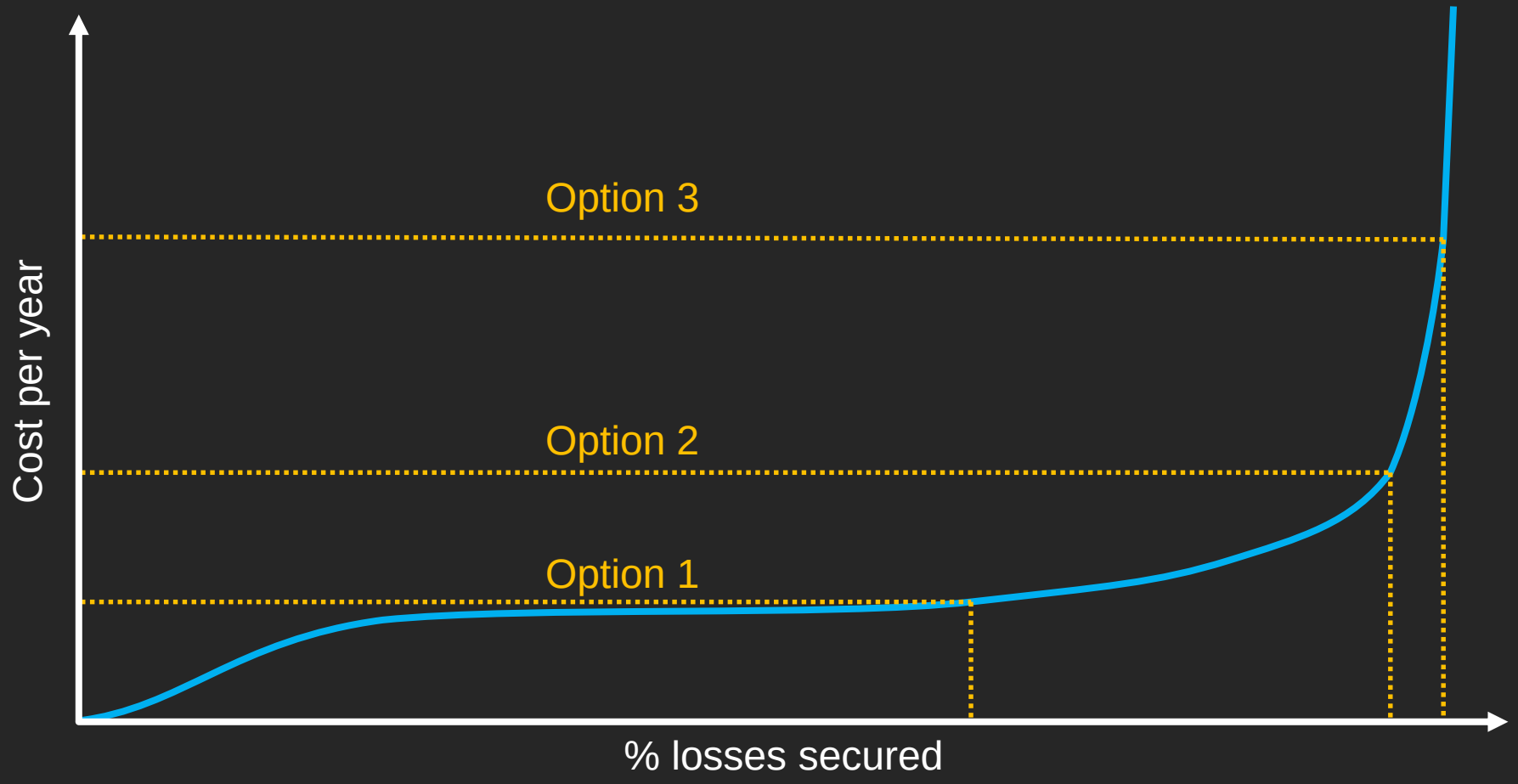
1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

Risk


e.g. 4,000 MW covers 100% of the time
e.g. 2,500 MW covers 99.9% losses
e.g. 1,800 MW covers 98% losses
Loss size
Load-duration of loss size


Control
Ancillary services required
Loss size
Cost per year

Report



Key questions

1. What do we mean by “reliability”?
2. How do you assess the price/cost?
3. How do you judge the right balance between the two?

- Use the Frequency Control Target Report to analyse and assess:
  - Potential size and likelihood of losses
  - Expected cost of mitigating to different sized losses
  - Overall cost vs. risk options for the system
- Industry consultation on results, to make and informed decision on where to balance between the two key objectives:
  - a reliable supply of electricity
  - at an affordable price