Enhanced Frequency Control Capability (EFCC)

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Overview

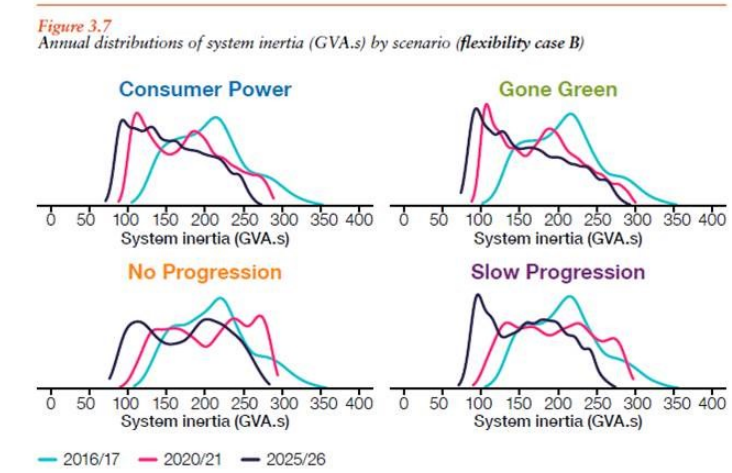
The EFCC Project

- The problem
- The challenge
- The control scheme
- The problem for the future

The problem

Reduction in Inertia

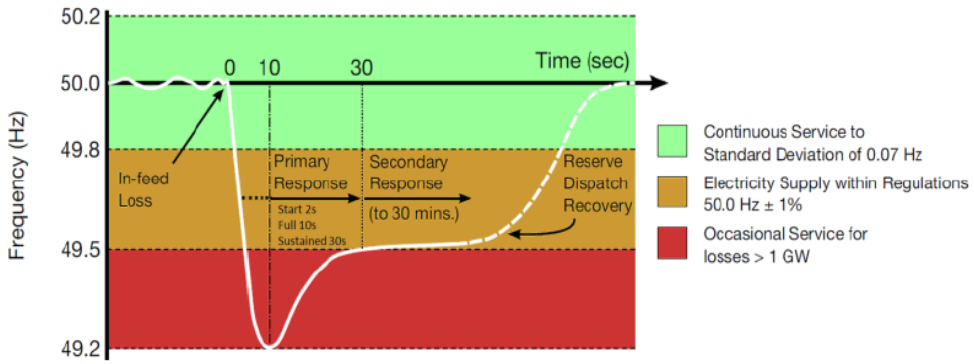
- Inertia in system is reducing
  - Sync. Gen coming offline
  - More wind coming online
- Faster and larger frequency drops
  - Risk hitting load shed limits
- Current frequency reserve cost £60m (as of 2013)
- Due to reduced inertia



National Grid inertia projections (ref 2016 SOF)

Fawley Power Station closed (SE)

Cockenzie Power Station demolished (Scotland)



National Grid operating limits

Project Aim

Move to non-conventional Frequency Response

Proposed solution:

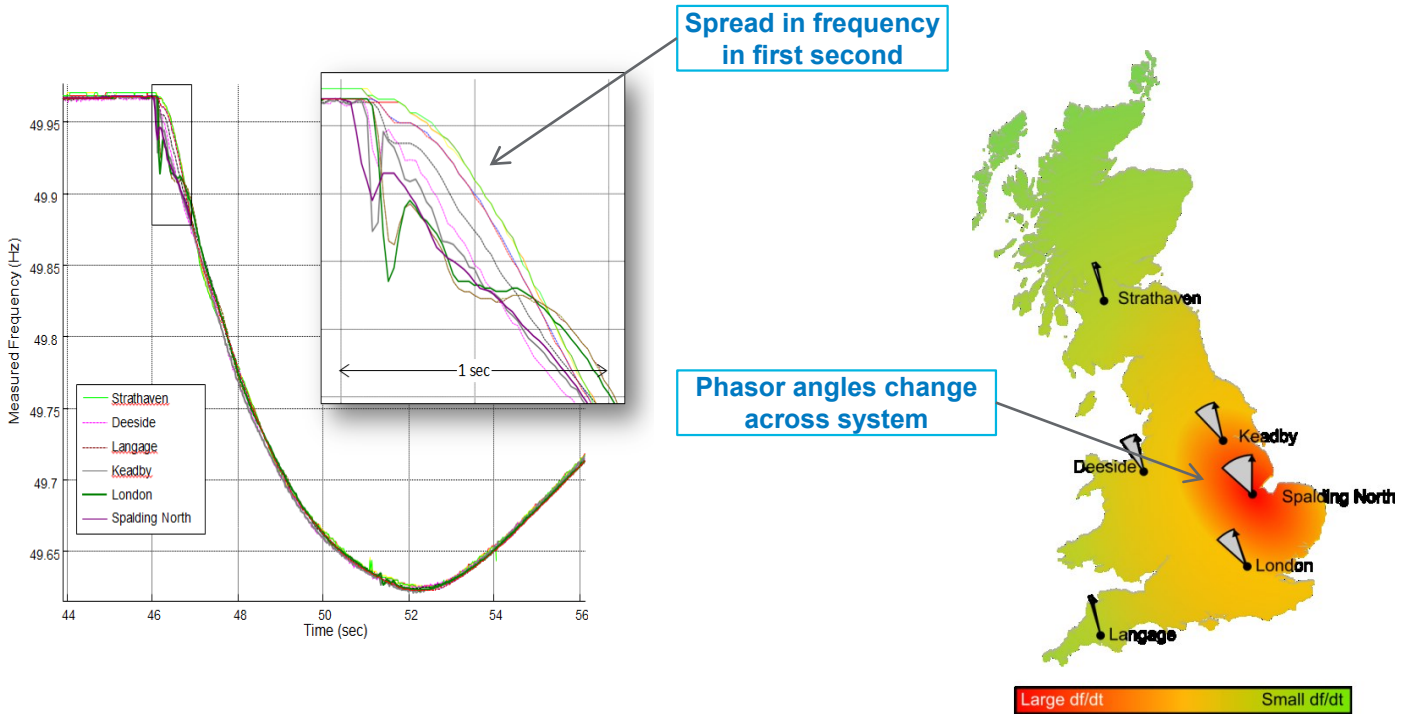
- Use non-conventional resources for frequency response
  - Wind
  - Solar
  - Battery
  - Demand Side Response
  - Fast acting Gas
- Provision response targets
  - Within 0.5-2s
  - Currently 2-10s
- Monitoring and Control Scheme
  - GE Development

The challenge

The Fast Frequency Response (FFR)Challenge

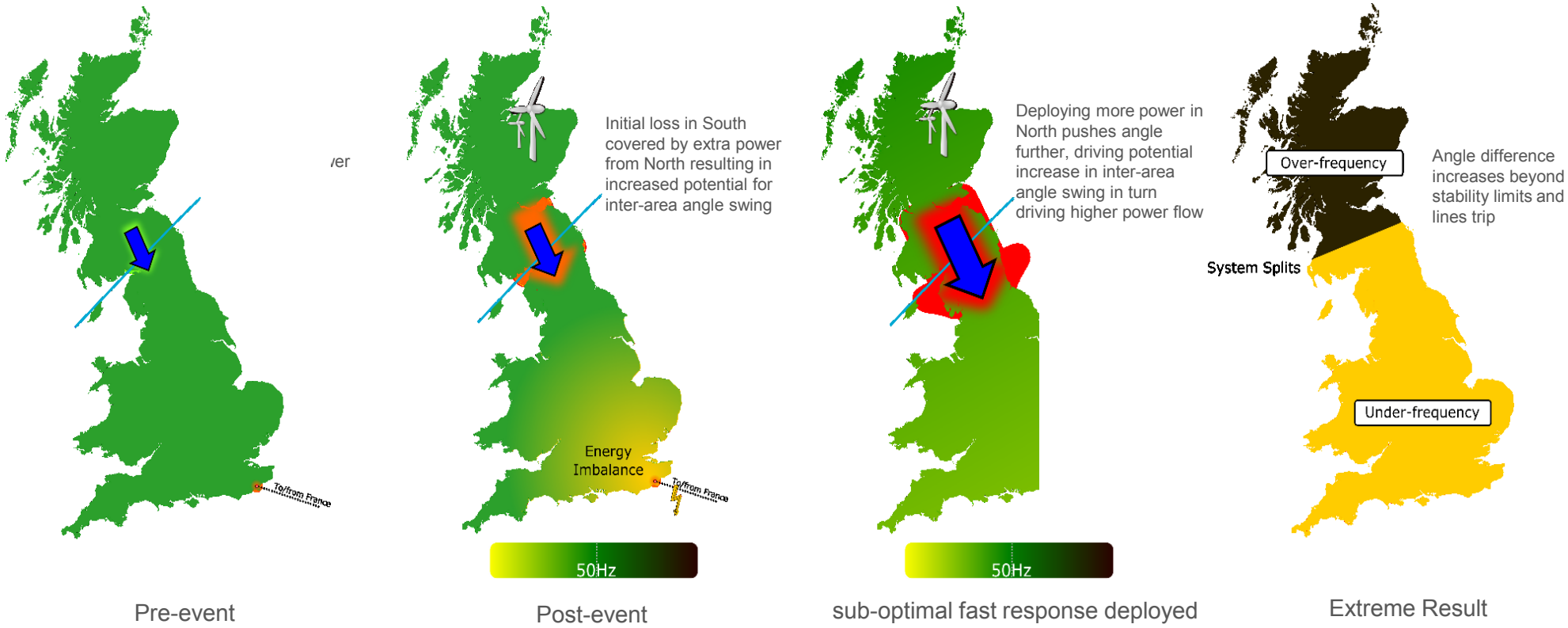
- Rate of Change of Frequency (RoCoF) Is not equal across system
- Dependent upon event proximity & Regional Inertia
- Reflects changes in power flows as the angle behaviour is perturbed

- What is the danger of Fast Frequency Response?
  - Similar time frame to first swing angular stability
  - Risk of system splitting or destabilising impact
- Consider angle behaviour for a coordinated response
  - Prioritise action closer to event
  - Using wide-area measurements



Potential implications from sub-optimal FFR location

Illustration of extreme behaviour during a frequency event



Pre-event

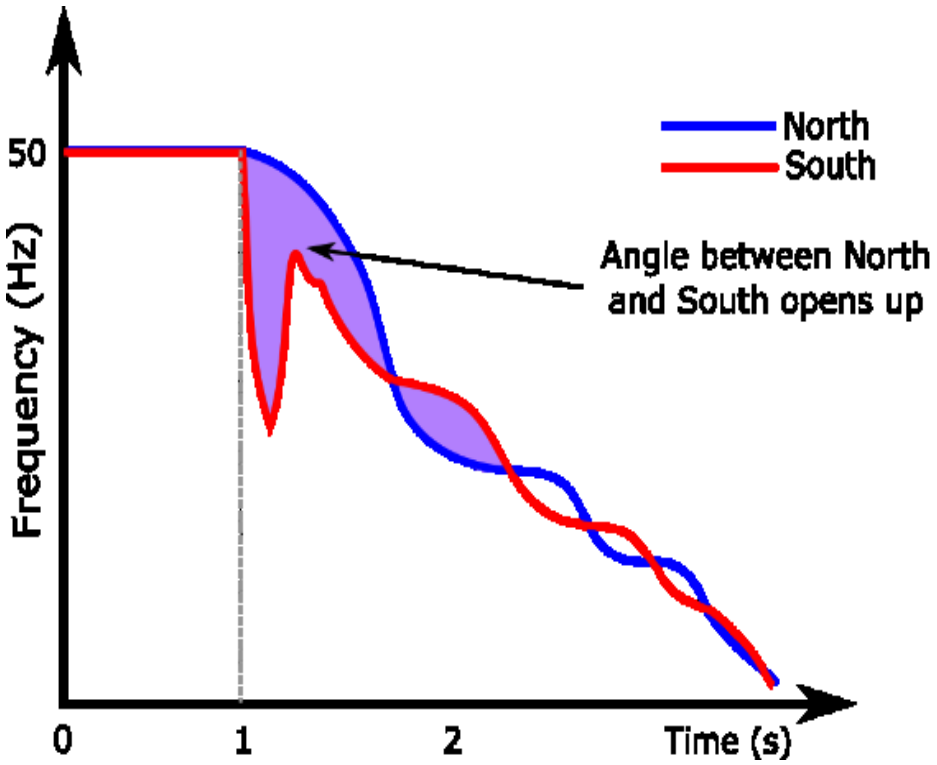
Post-event

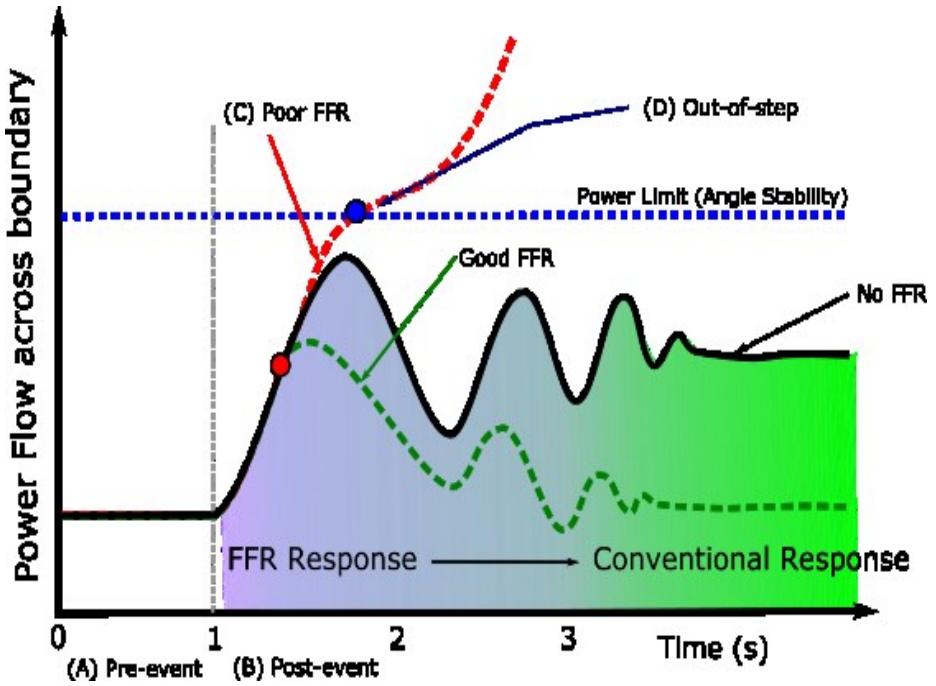
sub-optimal fast response deployed

Extreme Result

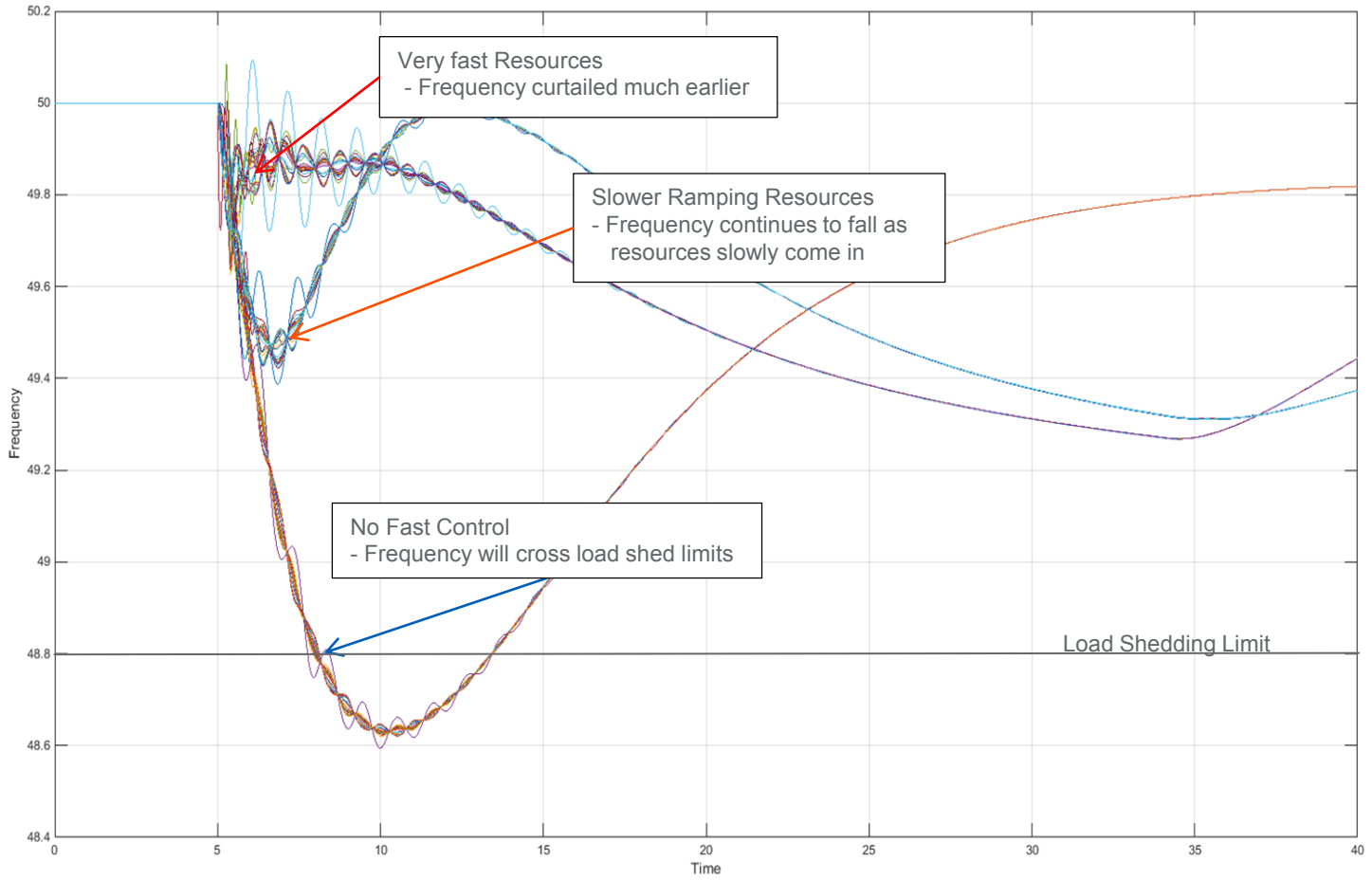
Target response

Maintain stable angle difference



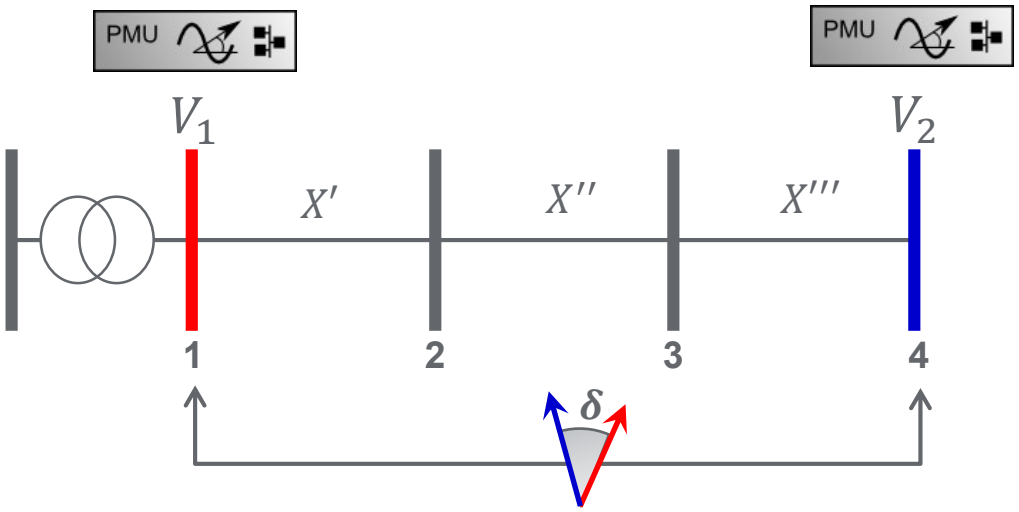


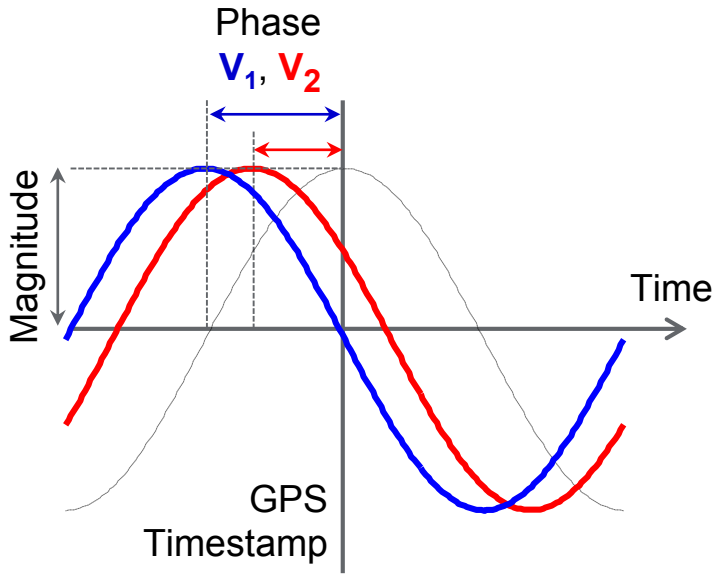
Effects of Speed of Response



The control scheme

Synchrophasor Measurement





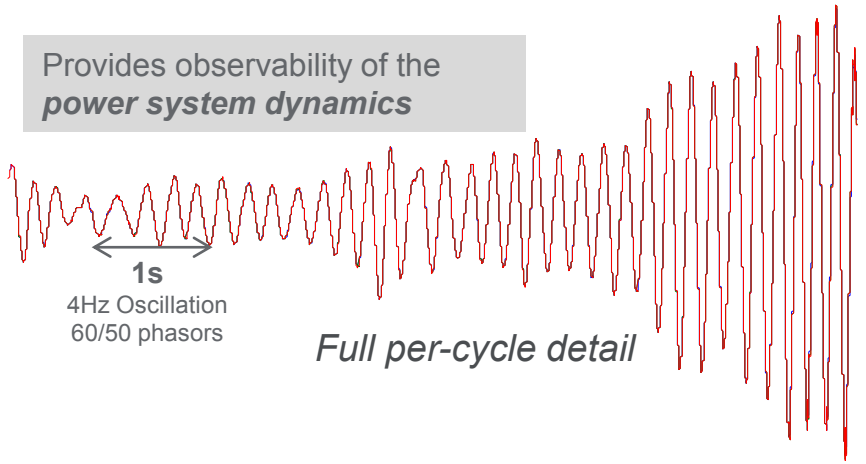
$$P = \frac{V_1 V_2}{X} \sin \delta$$

Angle difference is a ***summary measure of network capability***

Provides observability of the ***power system dynamics***

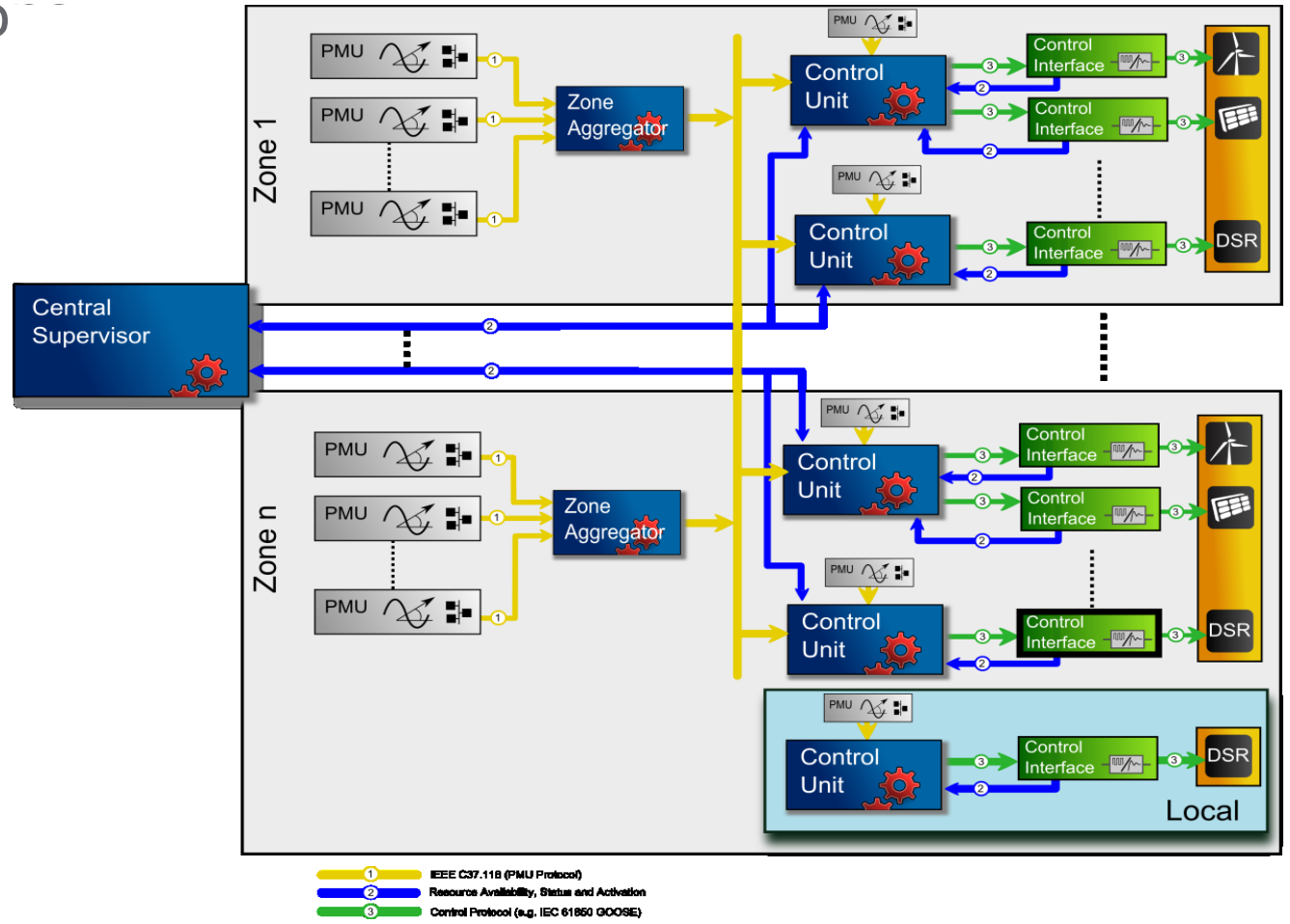
Phasor Measurement Unit (PMU)

- **GPS synchronised** measurements (V, I, F)
- **High-Resolution** (up to 1 frame per cycle)
- **Real-time** streaming

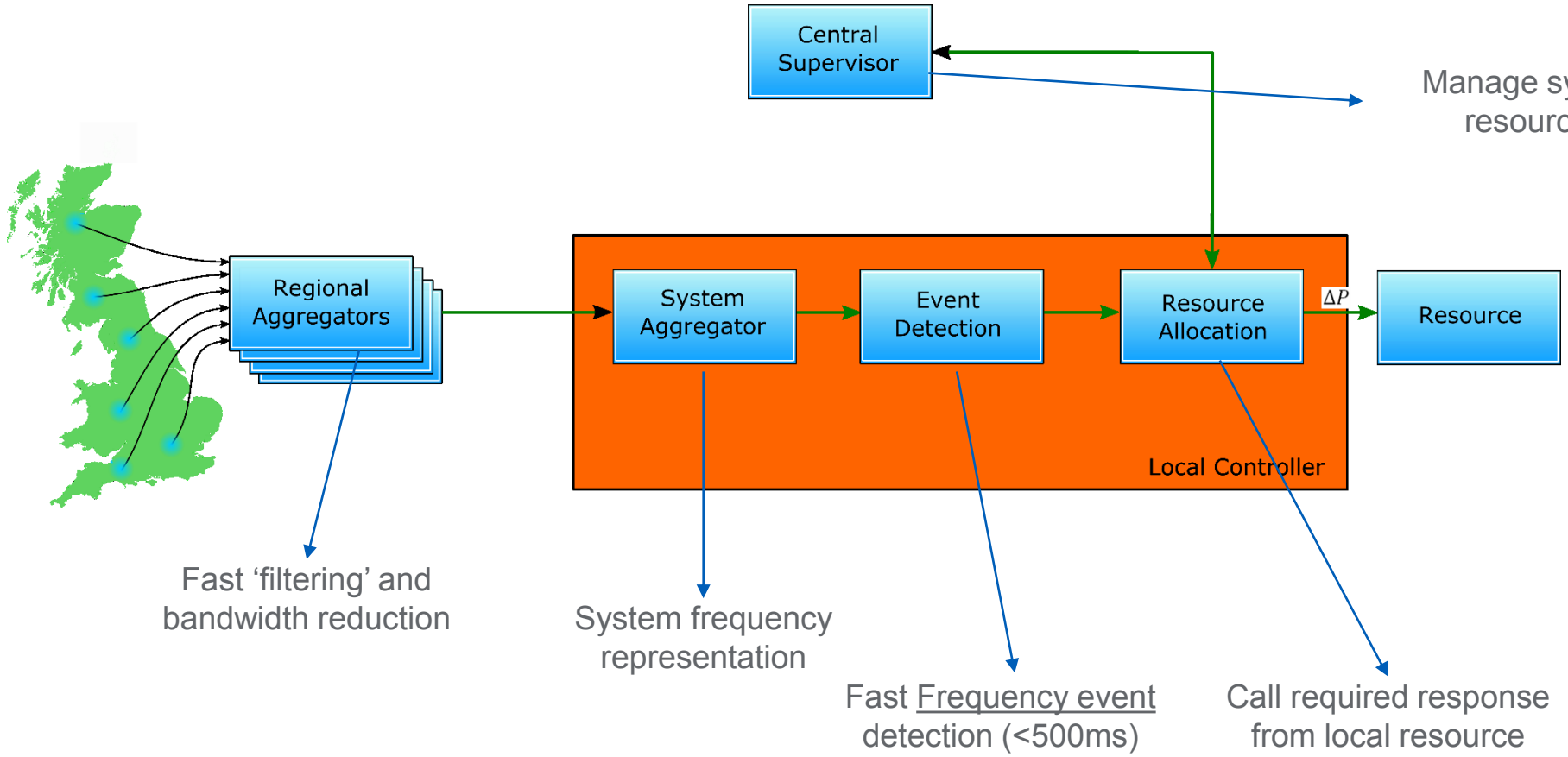


Distributed control scheme

- System split into a number of regio
  - Multiple distributed controllers
  - Aggregated signals broadcast to controllers
  - Resource information sent to Central Supervisor
- Distributed Control
  - Self regulation (autonomous decisions)
  - Communications - latency
  - Plug & play Infrastructure
  - Robust - no single point of failure
  - Graceful degradation

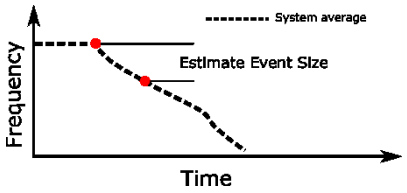


Control scheme applications

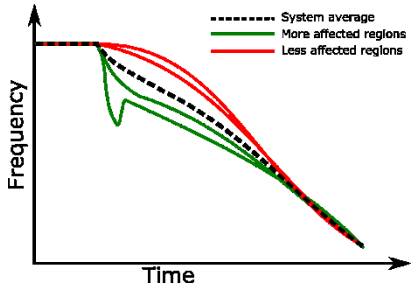


Resource allocation

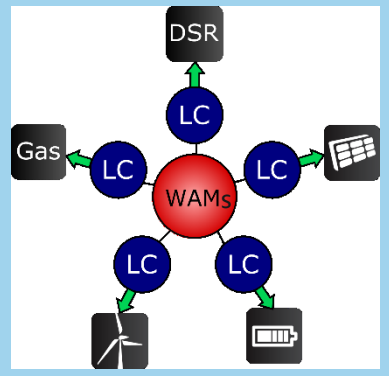
Estimate Total Response



Determine Regional Breakdown

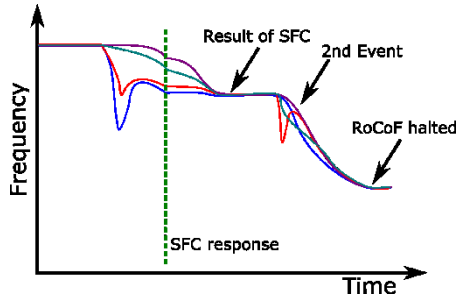


Determine Local Response



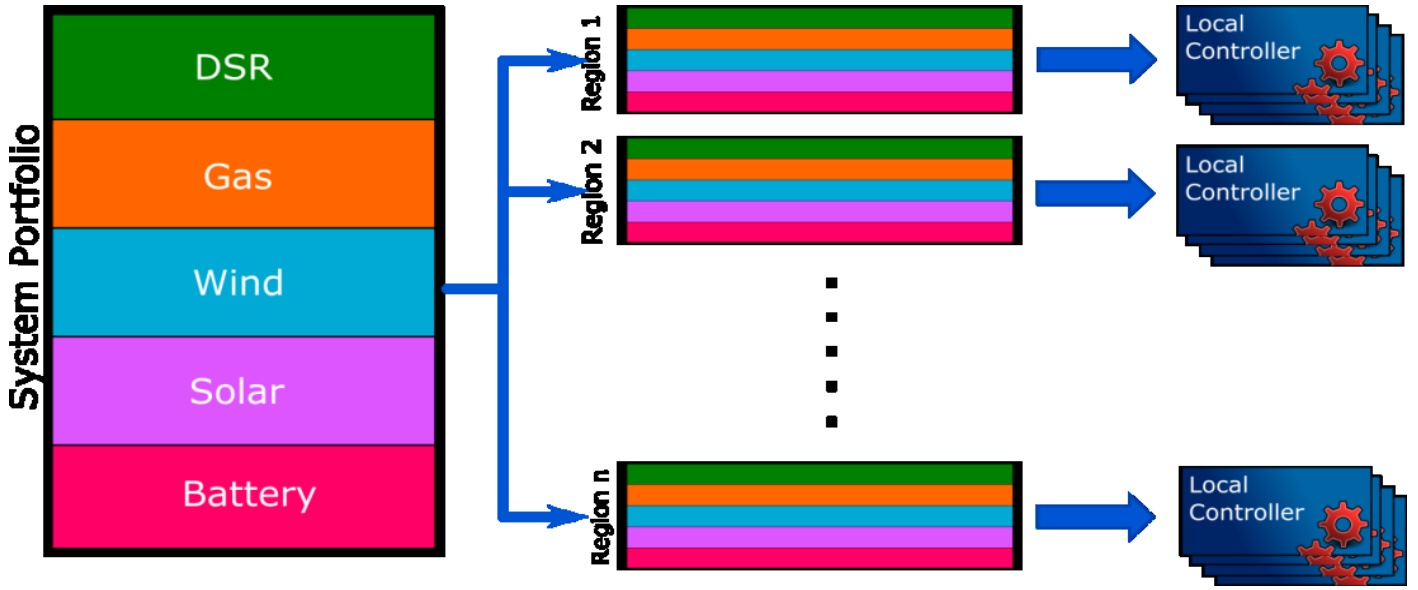
Using information received from Central Supervisor

Monitor Response



The role of the Central Supervisor

- Can see all the resources available in the system
- Ranks resources according to their characteristics (speed)
- Issues summary information down to each local controller



Optimisation

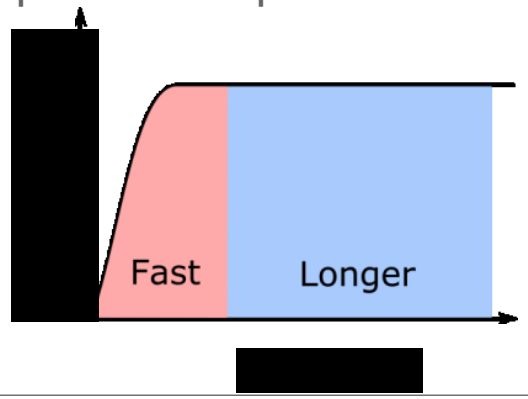
Ideal Response

- The ideal response is one that reduces the event's effect before the system degrades

For example:

- Region A loses 500 MW of generation at time 0s
- If 500 MW of load is tripped in Region A at time 0s, the event becomes negligible

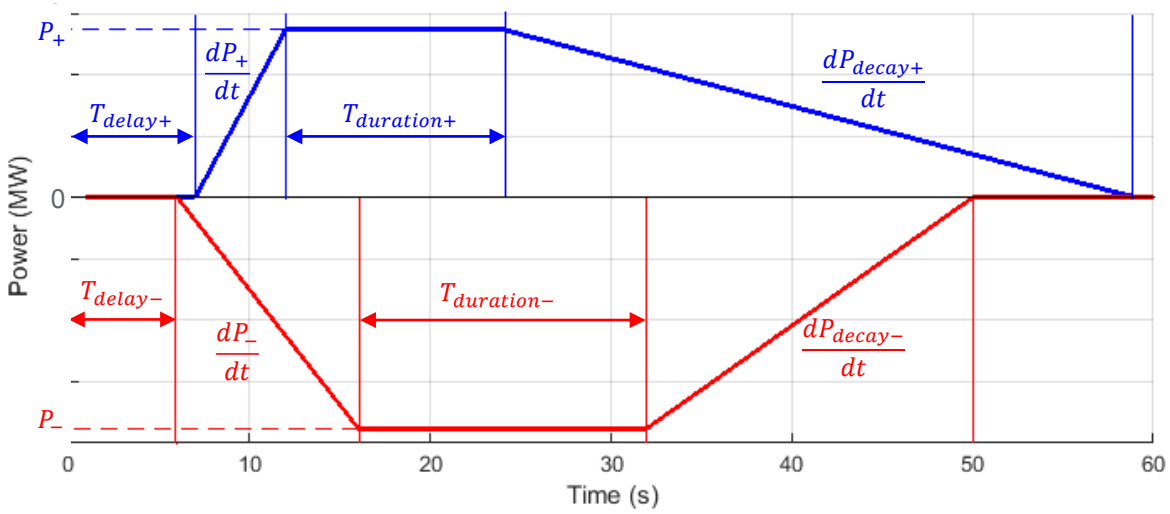
- Whilst a ~0s is not possible for a response-based system, it **provides a target** by which to rank responses
- Additionally:
  - Need to balance speed of response with **sustaining** periods, **handover** to traditional response



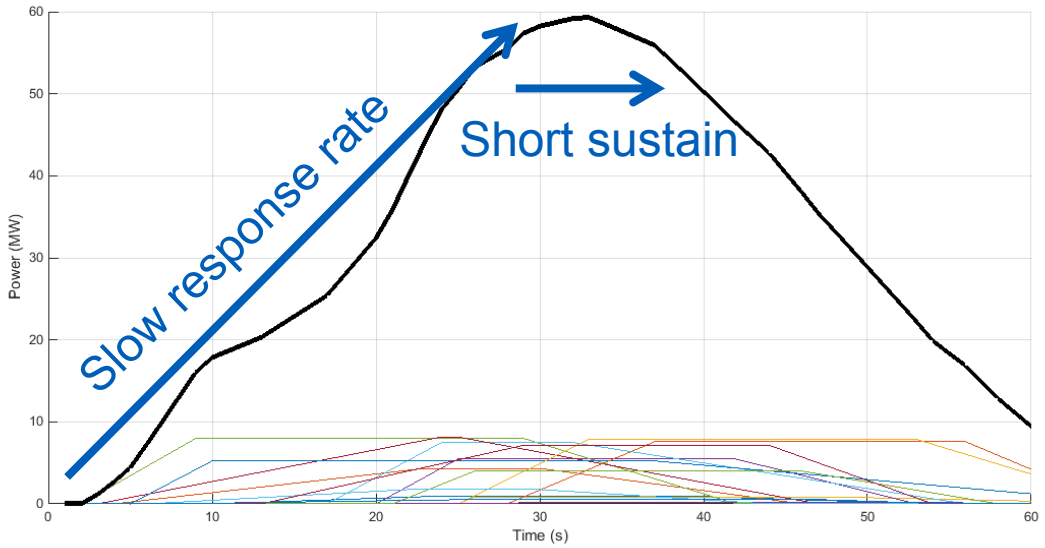
Square wave is best
- 0 s time delay
- Infinite ramp rate
- Sustained response

Quantifying Response

Total regional response

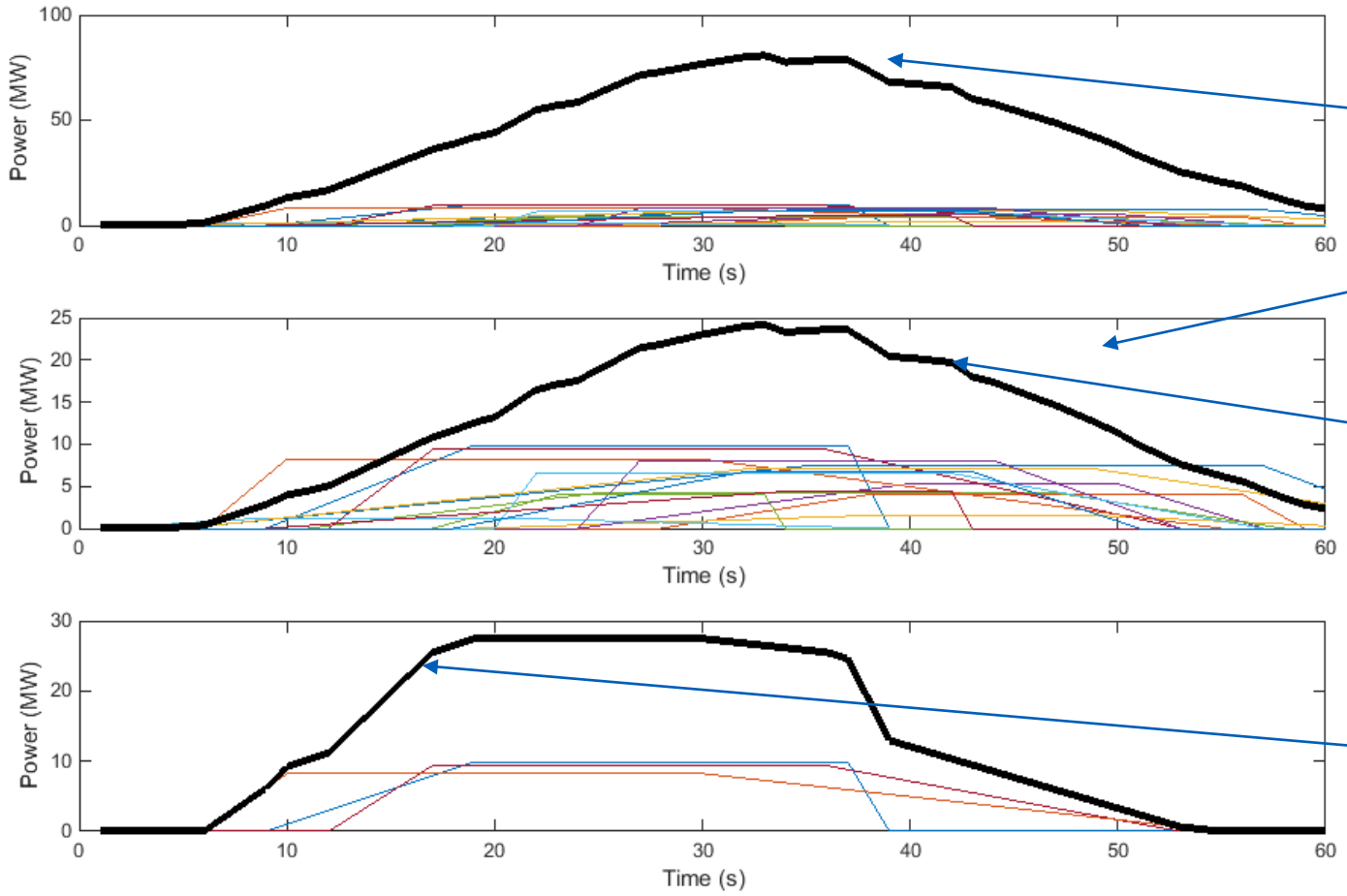


- Total response tends away from ‘ideal’ response



Deploying Response

Proportional deployment



If all resources were called upon at same time

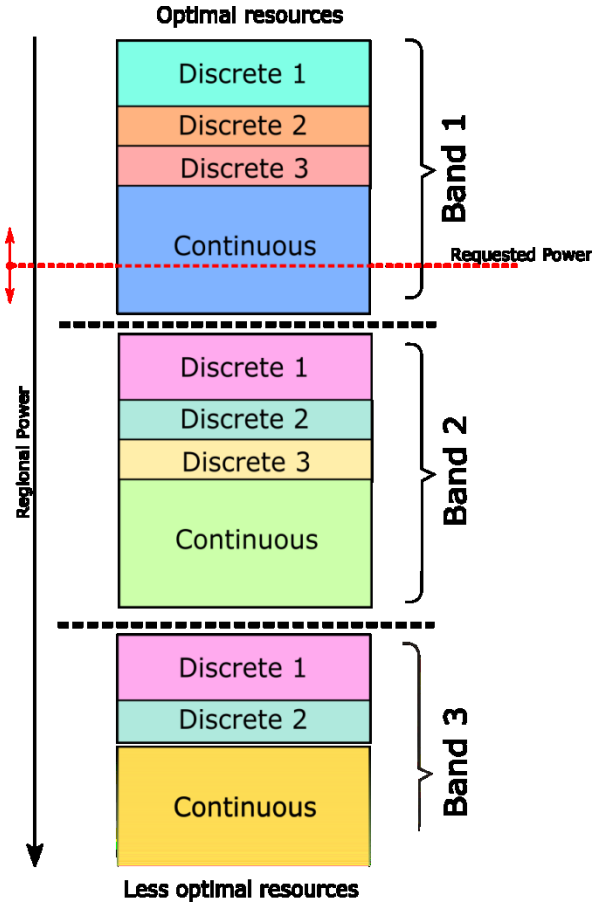
If a proportion (say 30%) of all resources were called upon

Sustain time may be longer for some resources at part-load

Selecting Resources allows shaping of the response characteristic

Current central supervisor output

- List of armed resources
- Ranked according to the results of the optimisation
- Simplified problem focusing on speed and duration
- Local controllers use this ranking for deployment



The problem for the future

What we have achieved so far

- ✓ Wide area visualisation
- ✓ Fast detection of system events
- ✓ Trialled and simulated:
  - Fast deployment of wide-area resources
  - Co-ordination of response

Question: How to scale and optimise resource management?

Current optimisation investigation

- Currently to find resources with best response characteristics:
  - Ramp rate
  - Long duration
  - Short delay time
- But could consider:
  - Resource cost
  - Location
  - Resource mix
  - System targets

Could be considered in complete picture of services

Ongoing work package investigation the optimisation

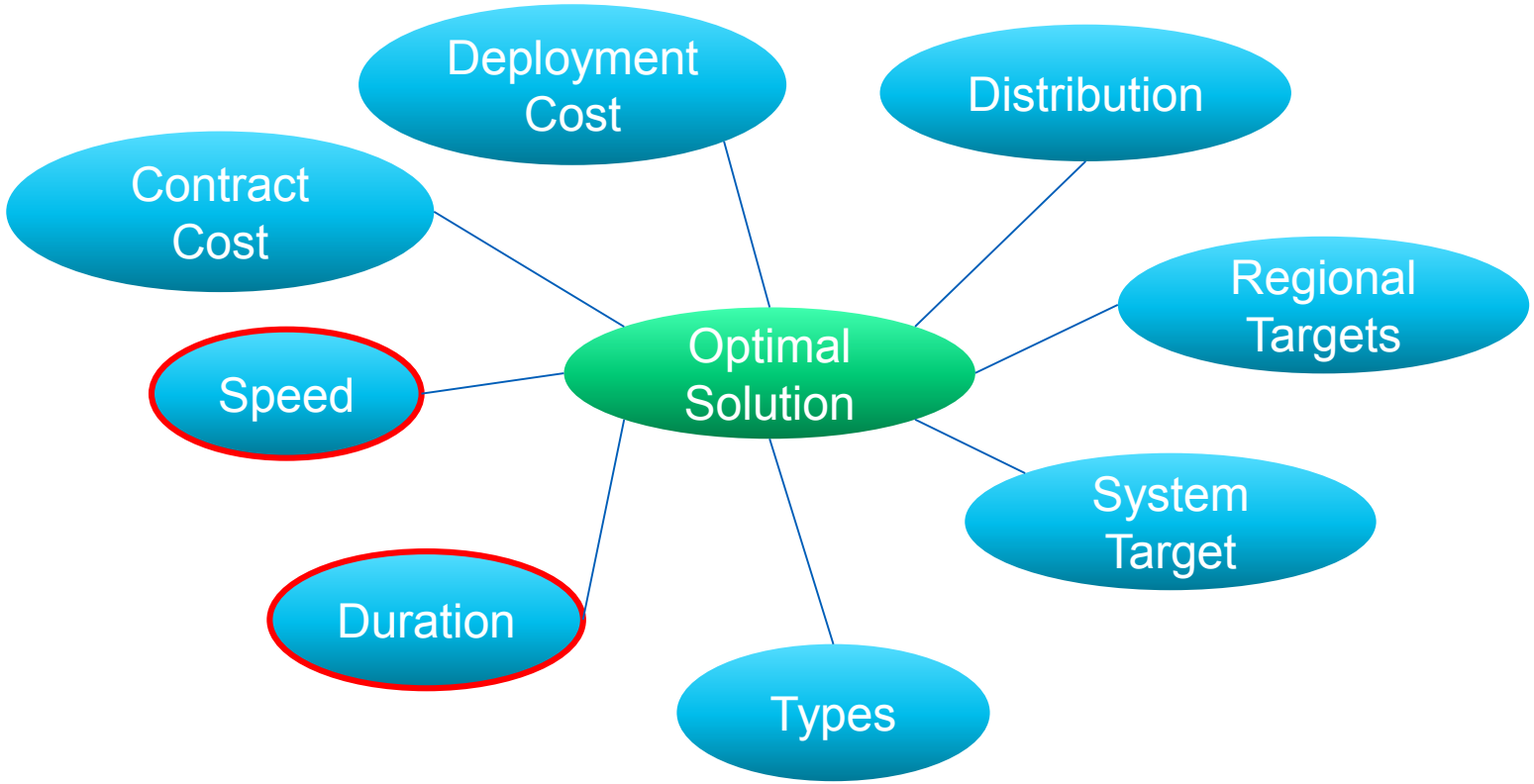
Resource mix

- A balance between fast and longer-term resources
- DSR has long duration and fast response, but do we want to prioritise load shedding? At what cost?
- Wind may provide short term, but must recover its energy
- Gas is slower to ramp up, but adds stability and duration
- Batteries have ideal characteristics, but may be costly
- PV is ideal for over-frequency, but requires curtailment for under frequency

Ideal solution for the Central Supervisor

Variables

Online optimisation based on live data – Ideally a 15 minute update

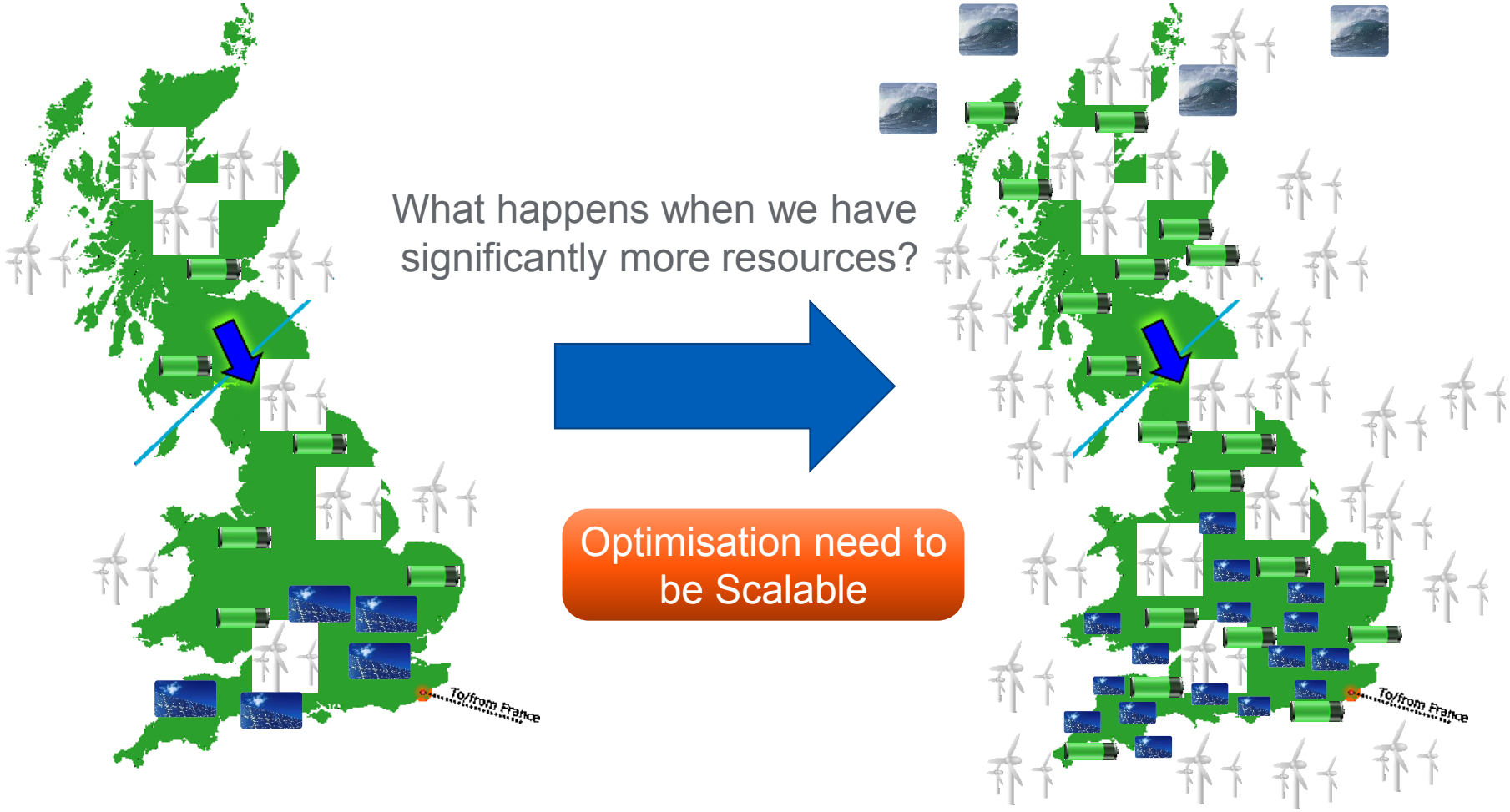


Minimise:
1. Deployment Cost (Offline or online?)

Maximise:
1. Speed of Response
2. Resource Duration (within limits)

Target
System/regional MWs

Scaling up the solution

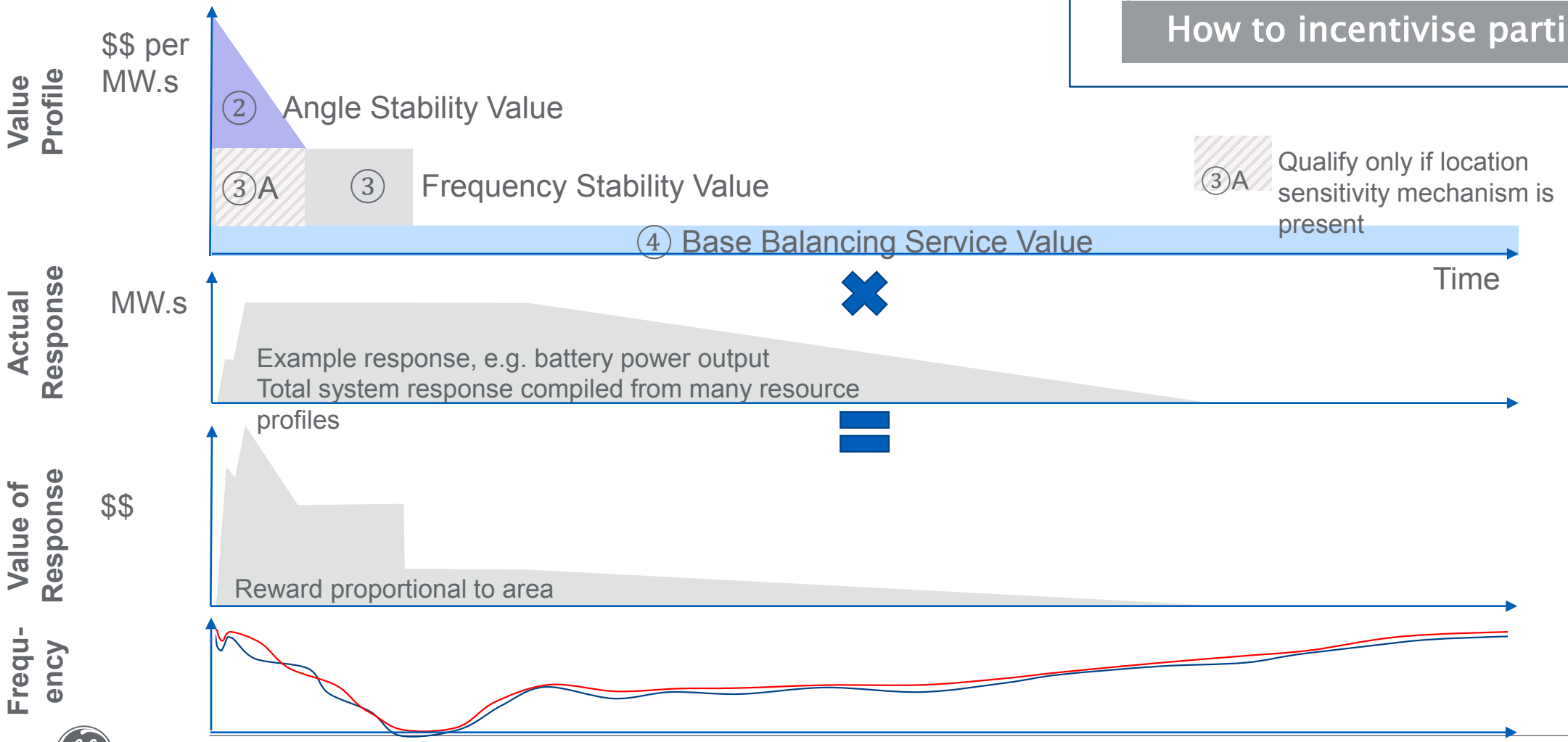


Valuing Fast Response

GRID VALUES

- Timing
- Location
- Energy
- Volume
- Predictability

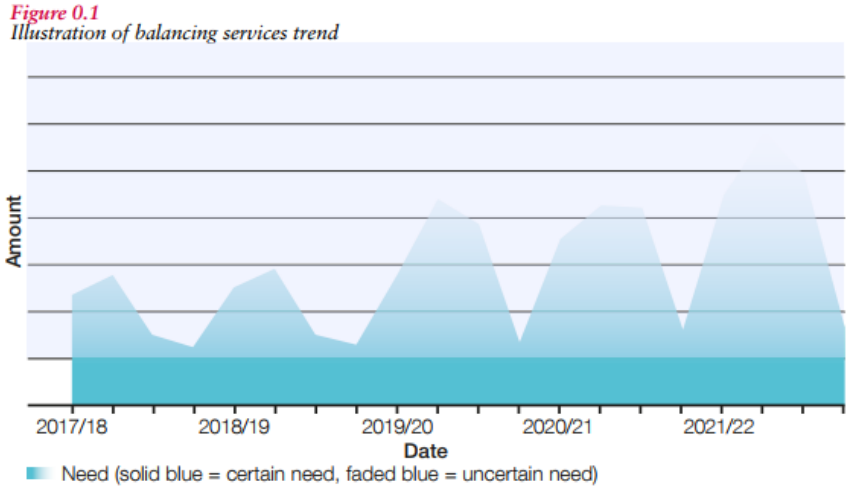
How to incentivise participants?



Future market challenges

Discussion Point: What could influence the markets?

National Grid currently reviewing balancing service market



Balancing services trend, [System Needs and Product Strategy 2017]

www2.nationalgrid.com/ futureofbalancingservices/

Longer term optimisation

Planning/investment stage (2-5 yr+)

Outputs:

- A list of recommended resources per region looking into the future.
- To be made available before the system inertia degrades to a point where the SFC scheme will be ineffective

Considerations:

- Resource characteristics
- Cost
- Region
- Forecasting Inertia degradation
- Seasonal requirement variations
- Avoid over-investment in best-paying areas

Tendency towards the more frequently affected areas should be minimised

Summary

- Rapid Frequency Response is technically possible
- There are a lot of ongoing discussions as to:

- What the service should look like?

- What would the future Market look like?

- What would the resultant optimisation problem look like?