System Operability Framework Event

March 26 2018

National Grid House, Warwick

Welcome

Beth Warnock

System Performance Manager

Welcome & Housekeeping

Planned fire drill at 10am

Toilets are located in the entry corridor to the conference suite

Please keep you mobile phone on silent please

You must be escorted around the building, just ask

Agenda

- 09:00 – 09:30 Welcome and System Operability Framework introduction
- 09:30 – 10:30 National and Regional trends and insights
- 10:30 – 10:50 Break
- 10:50 – 11:10 Voltage and frequency dependency
- 11:10 – 11:45 Real time event
- 11:45 – 12:05 Future of balancing services
- 12:05 – 12:15 Plan for afternoon
- 12:15 – 13:15 Lunch
- 13:15 – 15:30 Market stalls
- 14:30 – Tea & coffee

nationalgrid

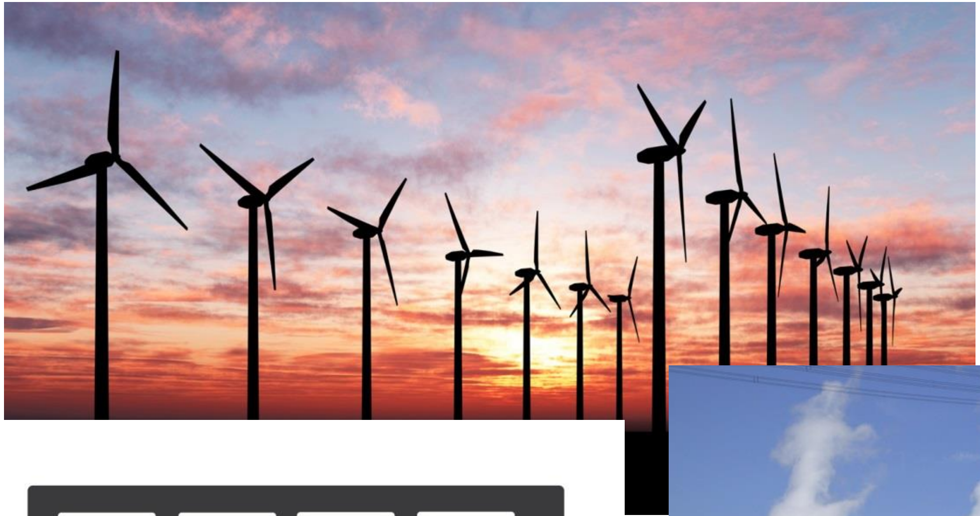
Introduction

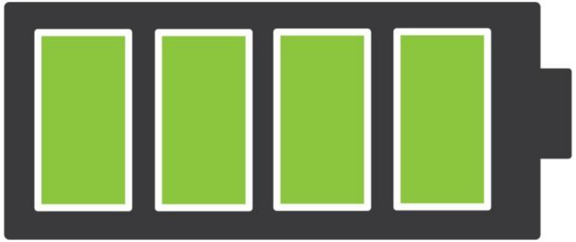
Graham Stein

Network Operability Manager

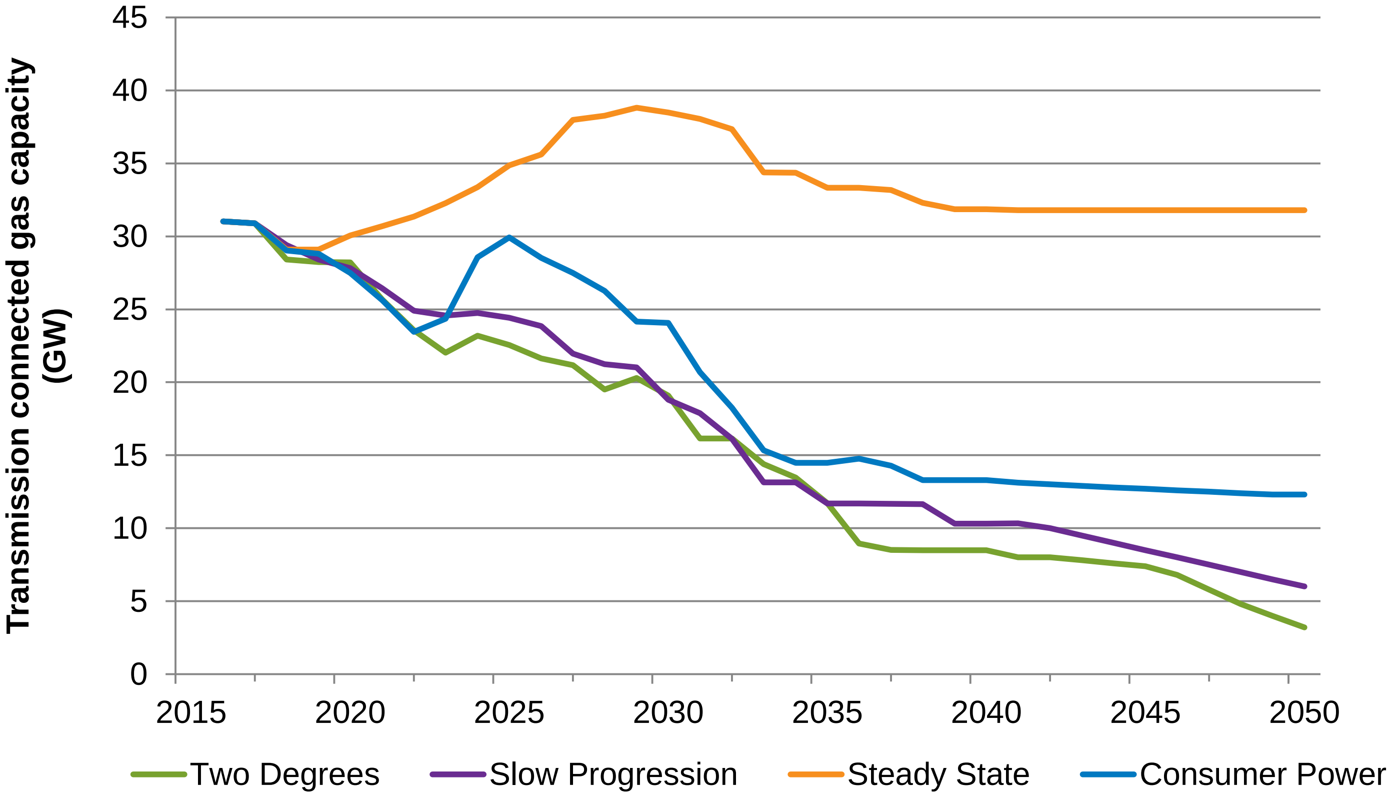
nationalgrid

Changing Generation & Demand



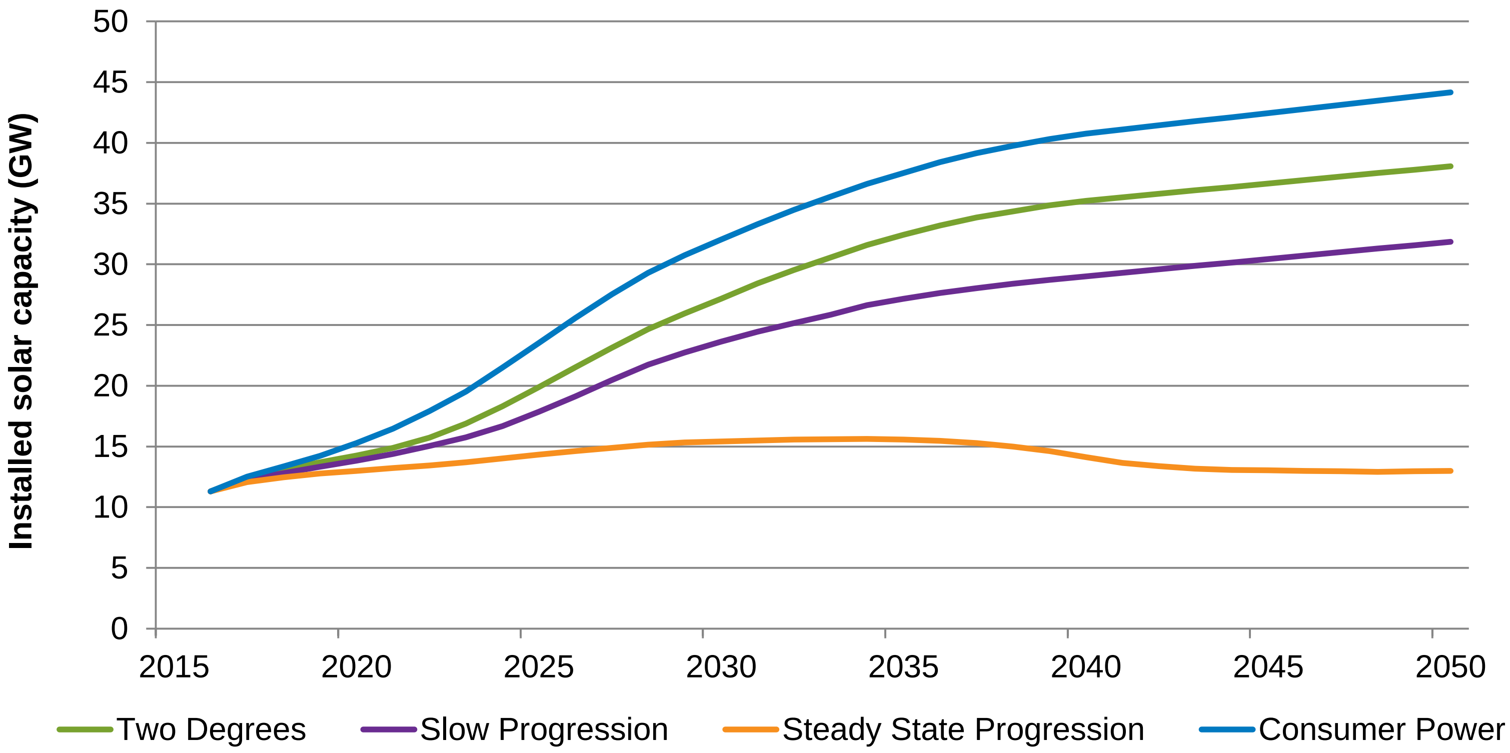


Future Energy Scenarios: Gas Generation



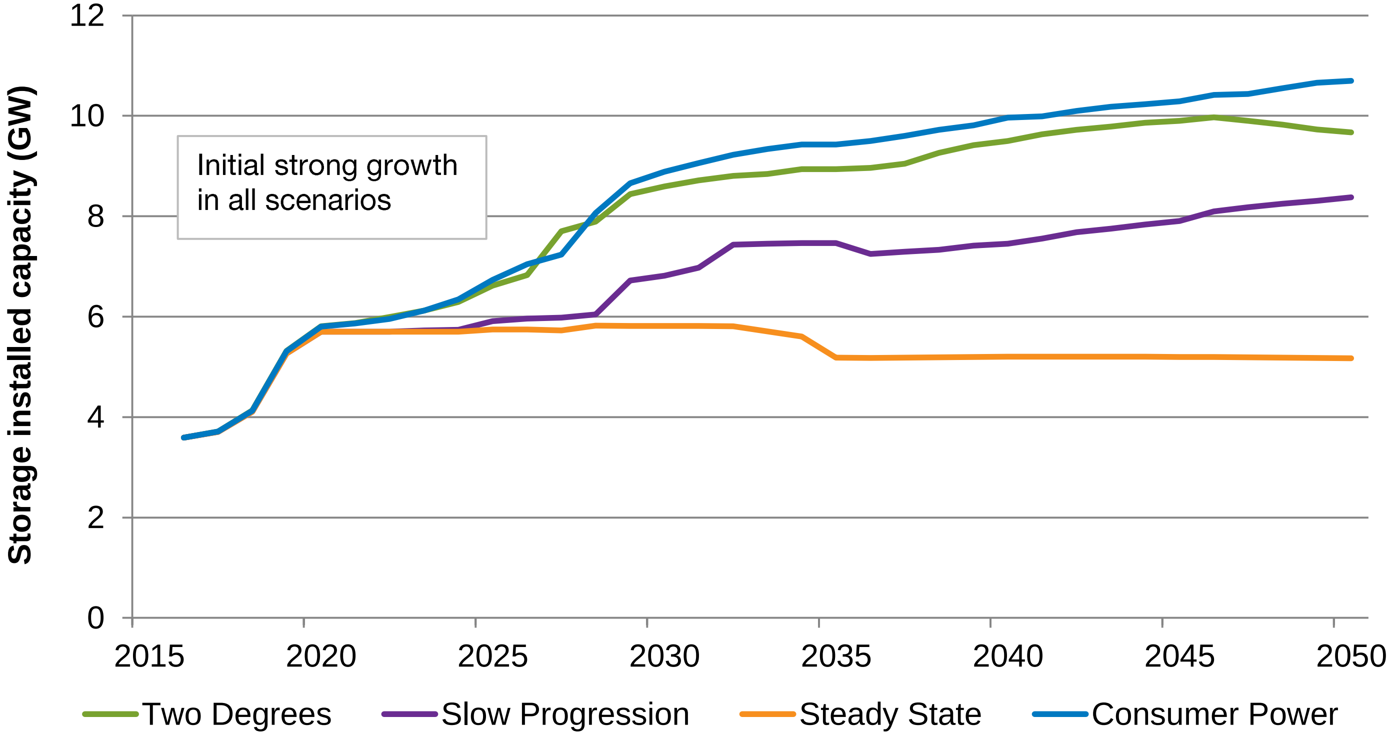
Future Energy Scenarios: Solar

nationalgrid

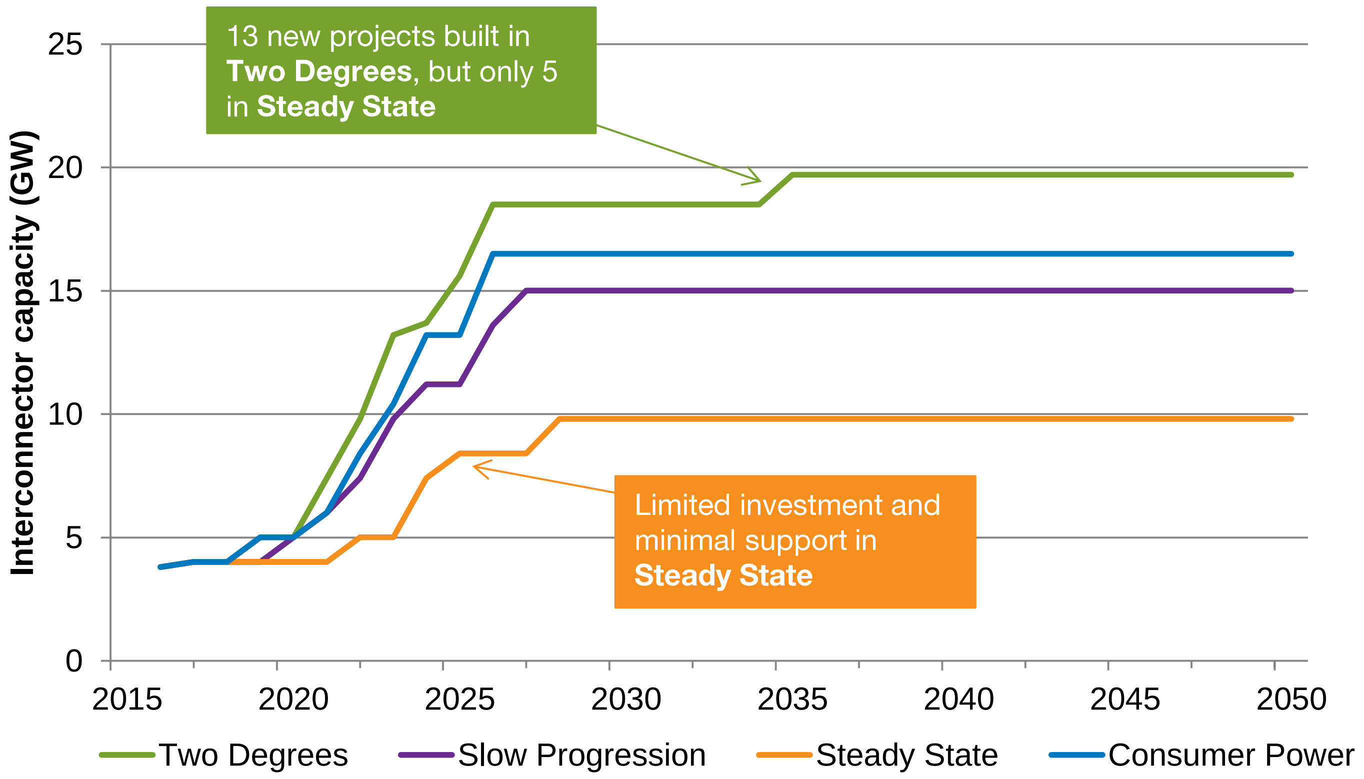


Future Energy Scenarios: Storage

nationalgrid



Future Energy Scenarios: Interconnectors



In 2017

nationalgrid

Transmission System Demand

On Sat 25 Mar 2017 transmission system demand (ITSDO) in Great Britain was for the first time ever lower during the afternoon than it was overnight due to high solar PV generation.

Great Britain goes without Coal Generation for 24 hours

Friday 21st April 2017 was the first 24-hour period since the 1880s where Great Britain went without coal-fired power stations.

National Grid Control R... @NGControlRoom Follow

#Solar has just broken another record in Great Britain, providing 8.7 GW (24.3% of demand)

5:08 am - 26 May 2017

National Grid Control Room @NGControlRoom · 25 Dec 2017

On Sunday #wind generated 35.1% of British electricity, more than gas 26.7%, nuclear 23.4%, imports 8.1%, biomass 2.4%, hydro 1.8%, storage 1.0%, coal 0.6%, solar 0.5%

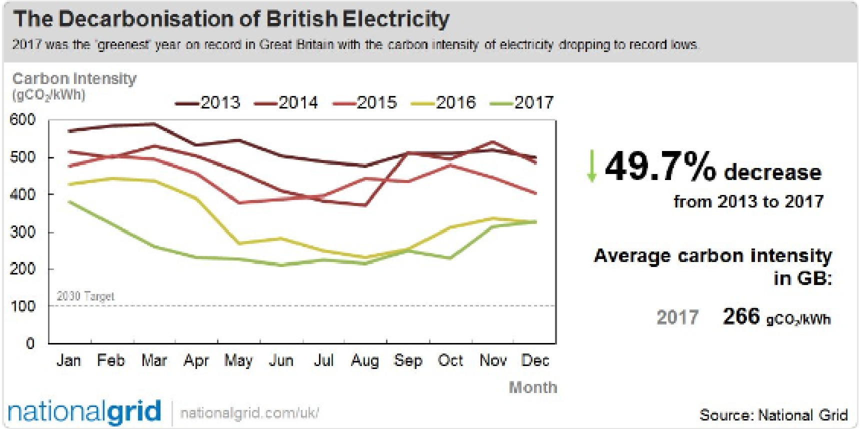
In 2017

nationalgrid

National Grid Control R...
@NGControlRoom

Follow

Low-carbon generation provided 45.4% of GB electricity in 2017, with #carbonintensity dropping to record lows and nearly halving since 2013 carbonintensity.org.uk



5:13 am - 4 Jan 2018

In 2018, so far..

nationalgrid

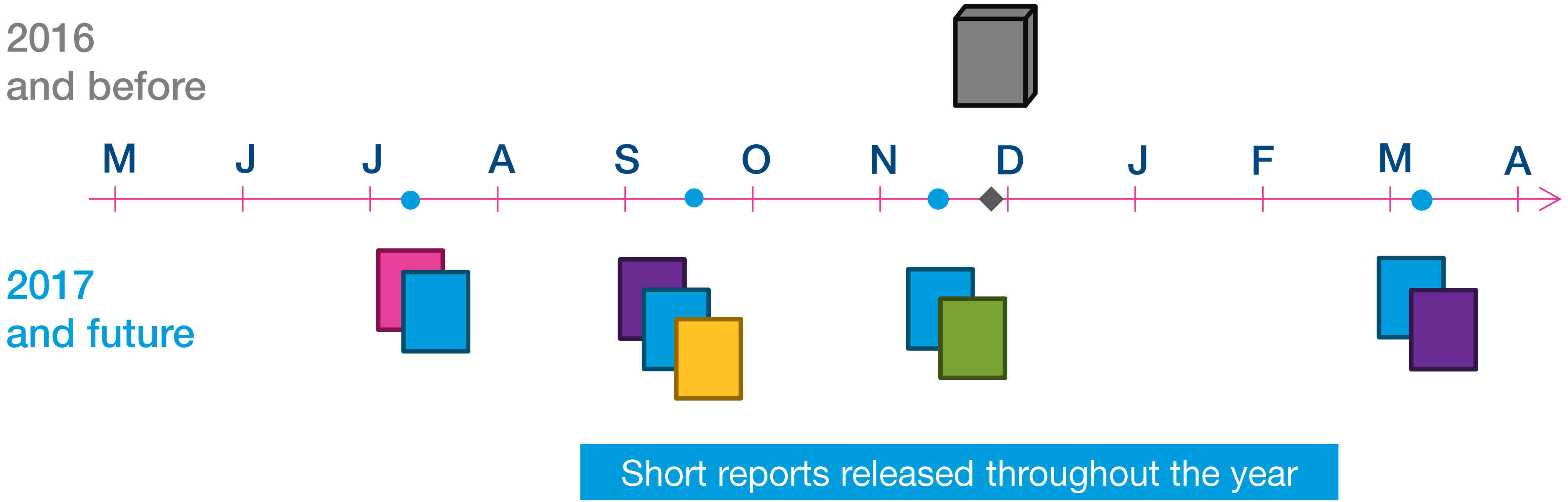
National Grid Control Room @NGControlRoom · Feb 25

At 11:00am low-carbon sources were providing 59.8% of GB electricity (wind 21.8%, nuclear 18.8%, solar 14.7%, biomass 3.7%, hydro 0.8%), national demand 38.1 GW

National Grid Control Room @NGControlRoom · Mar 18

Yesterday #wind generated 35.7% of British electricity, more than gas 20.3%, nuclear 17.6%, coal 12.9%, imports 6.0%, biomass 4.1%, solar 1.8%, storage 0.8%, hydro 0.6%, other 0.2%, national demand 858 GWh

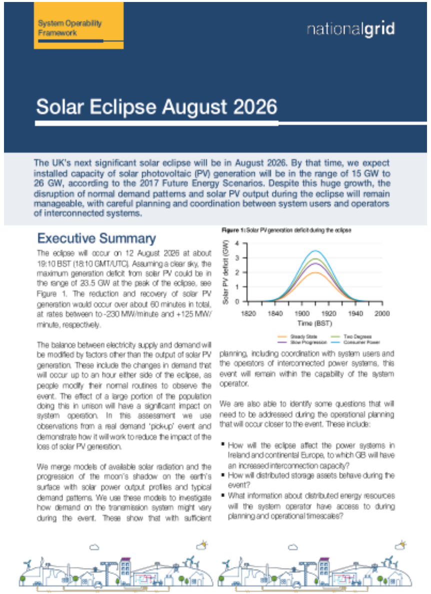
System Operability Framework has changed

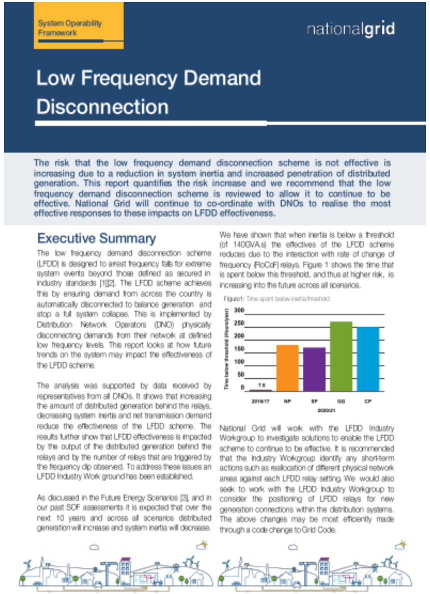


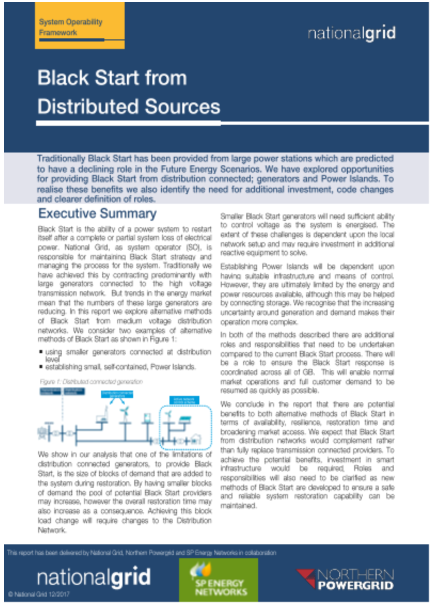
● Dates are illustrative

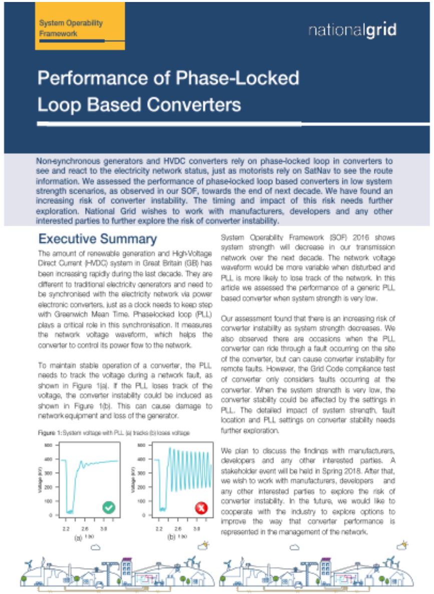
2017 SOF Publications

nationalgrid









Product Strategy Roadmaps

nationalgrid

System Operability Framework Analysis

Product Strategy Roadmaps

Reserve and response	Black start	Reactive power	Thermal constraints
Published	Coming this year		

https://www.nationalgrid.com/uk/electricity/balancing-services/future-balancing-services

Trends and Insights

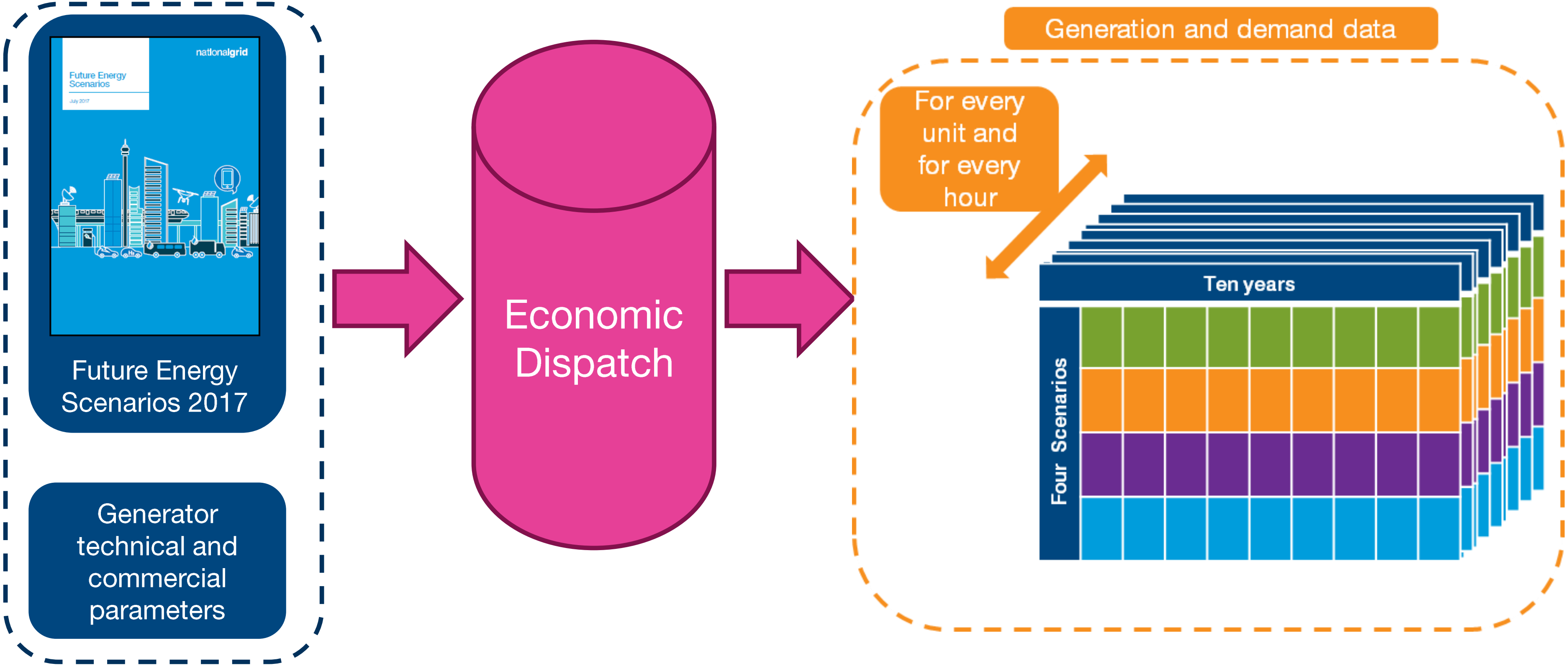
Ben Gomersall - Power System Engineer
Yun Li - Power System Engineer

Overview

nationalgrid

- Our new data set
- National trends and insights
- Regional trends and insights
- Q&A

Method



nationalgrid
Future Energy Scenarios
Future Energy Scenarios 2017
Generator technical and commercial parameters
Economic Dispatch
Generation and demand data
For every unit and for every hour
Ten years
Four Scenarios

Using this data

Data treasure trove
How will the system operate over the next 10 years?

What are the challenges? When they will appear? How big they will be?

Today we have our first look
Over the next year we will dive deeper into specific issues

National Trends and Insights

Key Messages

The system is becoming less operable without intervention

We need to transform the industry's approach to operability

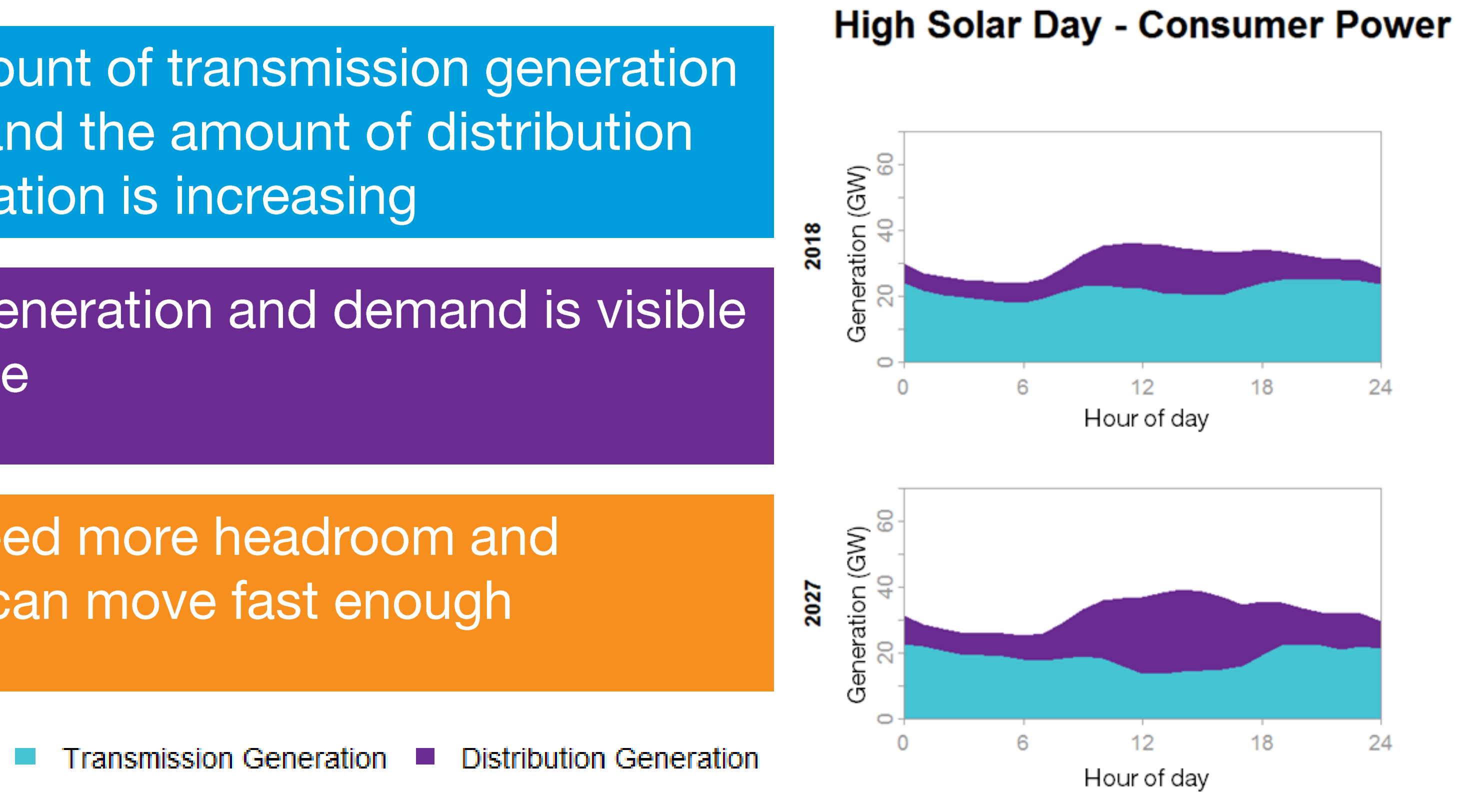
We will collaborate on new approaches to system operability

Flexibility

Trend: The amount of transmission generation is decreasing and the amount of distribution connect generation is increasing

Insight: Less generation and demand is visible and controllable

Actions: We need more headroom and footroom that can move fast enough



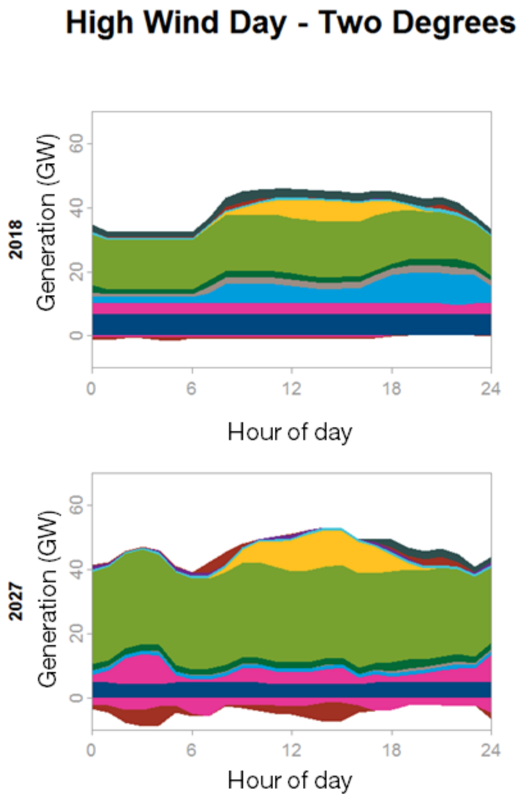
Wind & Solar

Trend: The amount of solar and wind is increasing

Insight: More generation and demand imbalances due to forecast uncertainty

Actions: We need to continue to improve our forecast methods and ensure enough flexibility

Wind
Solar



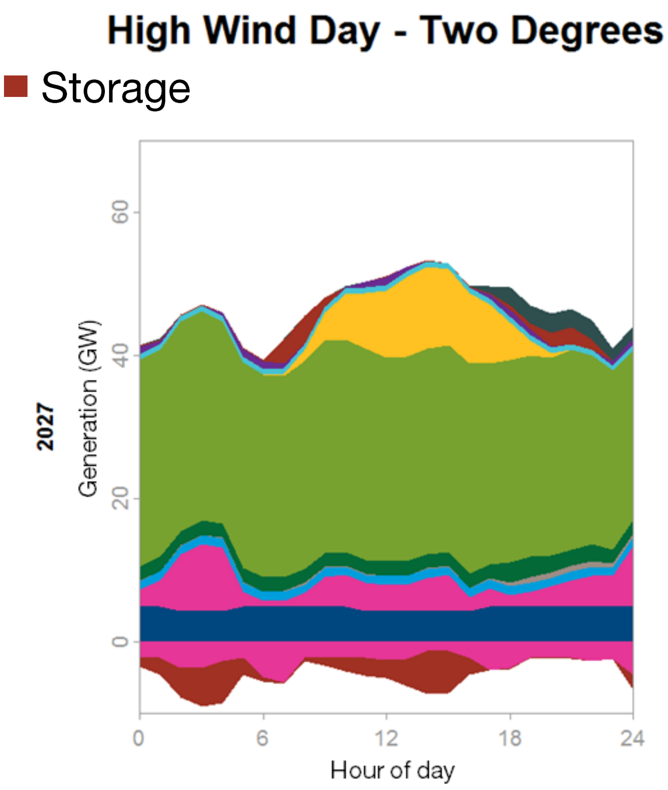
Biomass
CCS
Interconnector Export
Storage Demand
Nuclear
Interconnector Import
Gas
Coal
Gas Oil
Diesel
CHP
Hydro
Marine
Storage Generation
Other

Storage

Trend: Storage in increasing

Insight: Data shows it operating beneficially but it could cause operability issues

Actions: Consider operability in market design

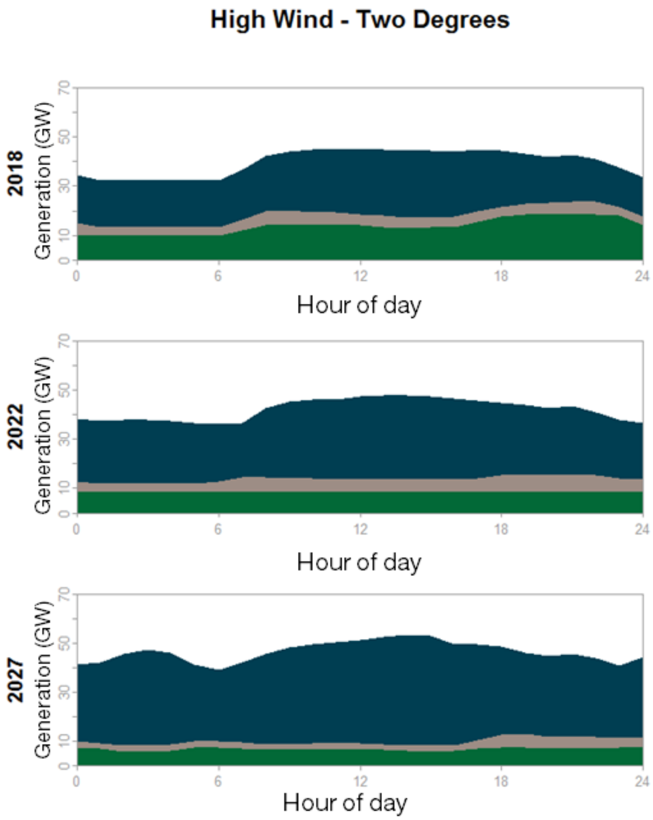


Synchronous Generation: Fault level

Trend: Synchronous generation is declining causing a decline in fault levels

Insight: Impacting on: Protection, Stability and Power Quality

Actions: We need a better understanding of the impact of declining fault levels



Transmission Synchronous
All Non-synchronous
Distribution Synchronous

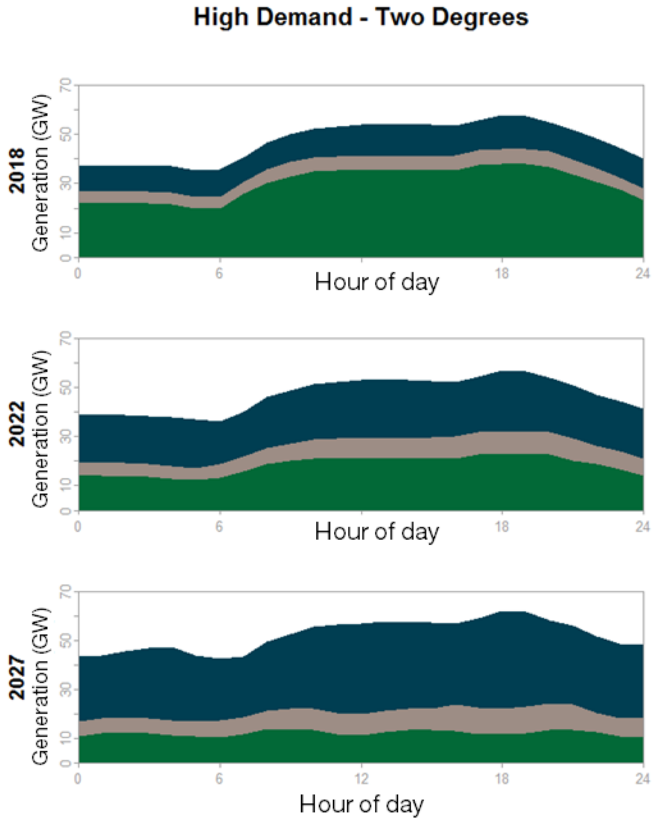
Synchronous Generation: Voltage

nationalgrid

Trend: Synchronous generation is declining causing reduction in voltage support

Insight: It will be harder to keep steady state voltages and less dynamic support during a fault

Actions: Look out for the “Reactive Power Roadmap”

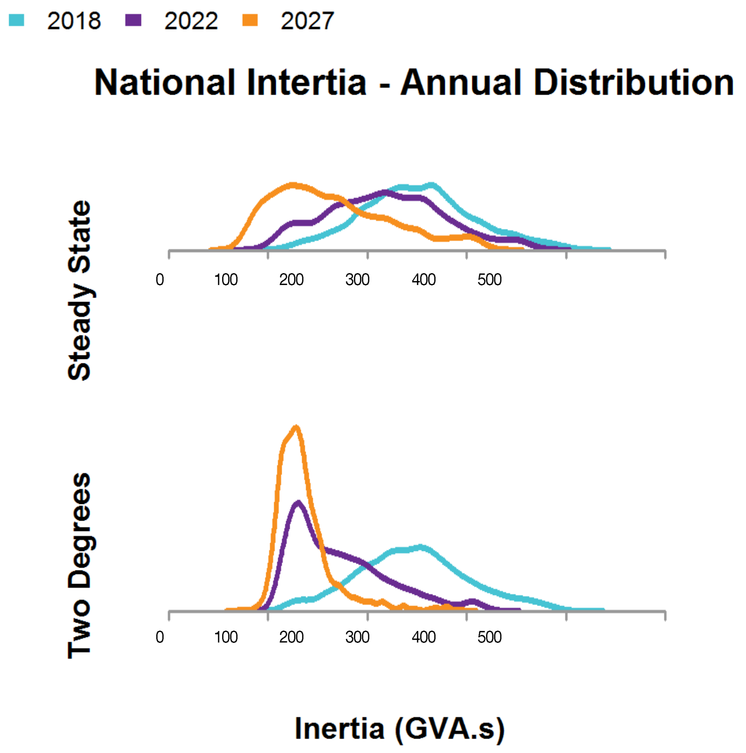


Synchronous Generation: Inertia

Trend: Synchronous generation is declining causing reduction in inertia

Insight: Frequency will move faster and keeping it within limits will be more difficult

Actions: See the “Product Roadmap for Frequency Response & Reserve”



Regional Trends and Insights

Key Messages

High electricity flows seen in the transmission network in all four seasons

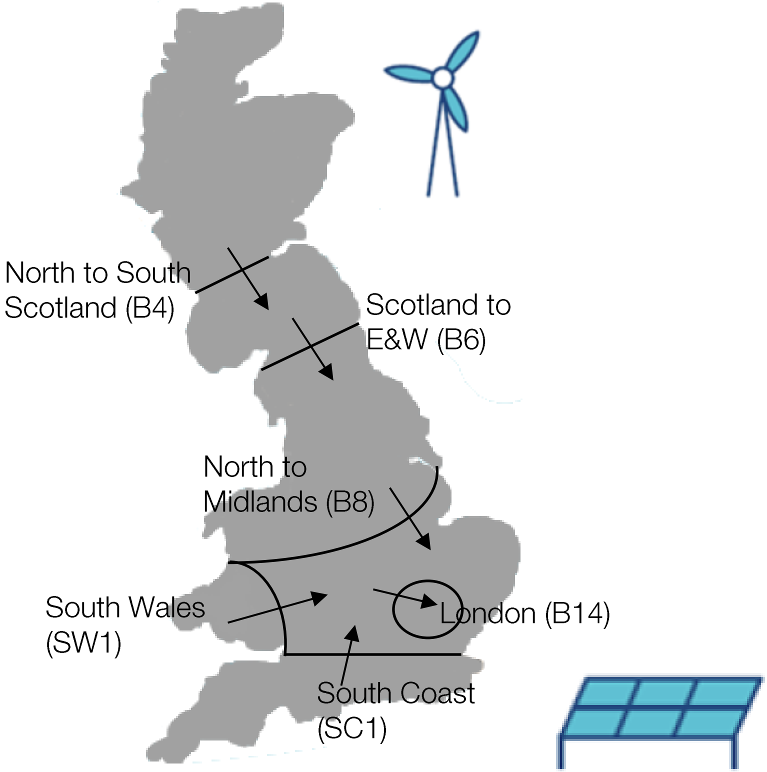
Increasing volatility of electricity flows

Low regional synchronous generation will become more frequent

More flexible resources and voltage support will be required

We will collaborate with the wider industry to understand how operability challenges affect them

Regional Power Flows

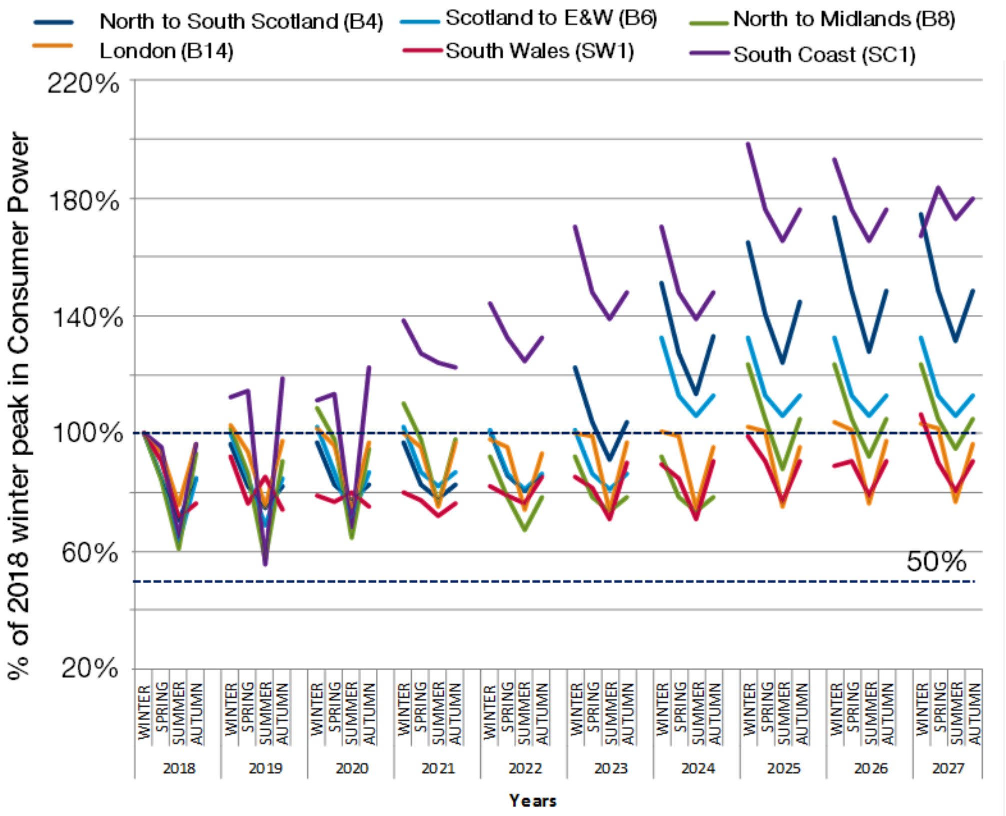


Seasonal Peak Flows

Trend: High peak flows in all seasons

Insight: Winter peak is no longer the only time the network is heavily used

Actions: Year-round analysis needs to be considered

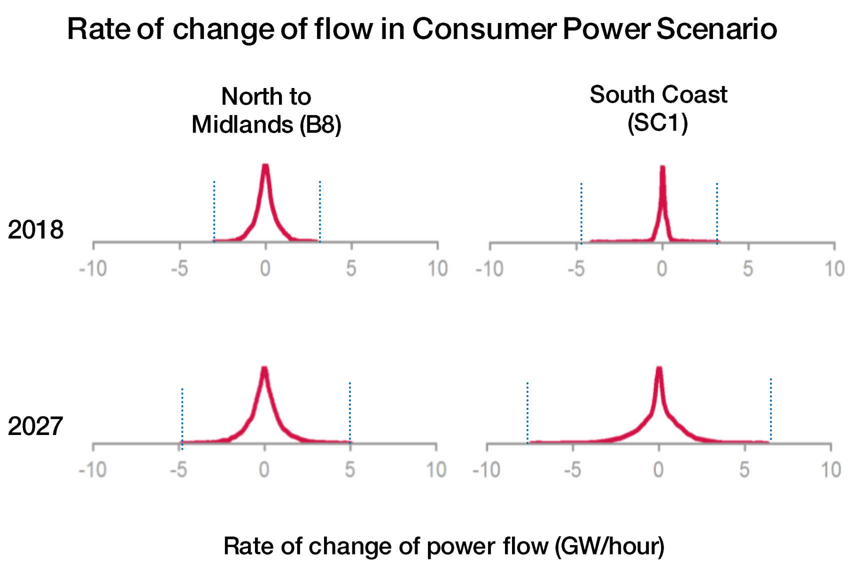


Rate of Change of Flow

Trend: Increasing volatility of power flows from one region to another

Insight: More flexible resources and voltage support are needed

Actions: Continuing to improve our forecast methods

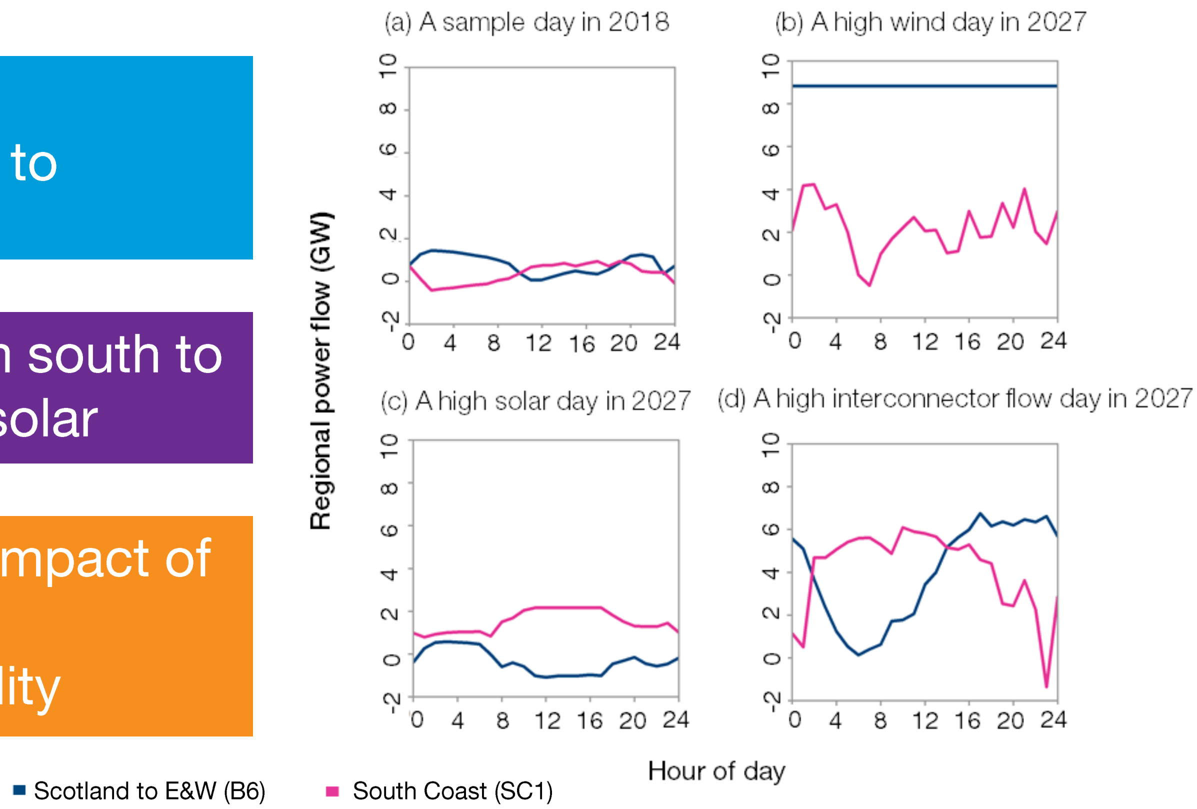


Case Studies

Trend: Wind, solar and interconnector contribute to increasing volatility

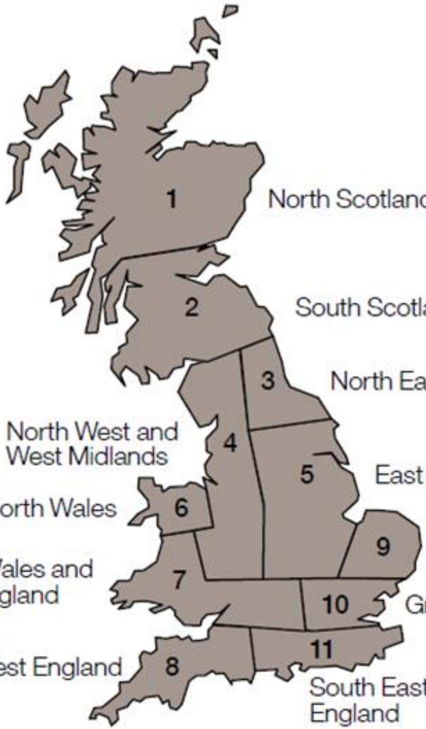
Insight: Reverse flow from south to north when there is high solar

Actions: Understand the impact of Pan-European market arrangements on operability



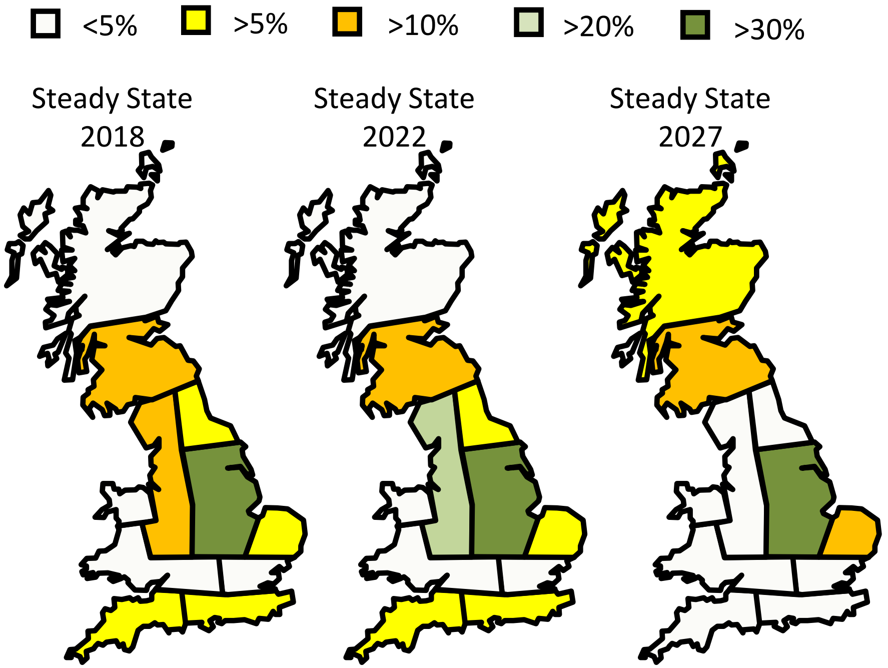
Regional Synchronous Generation

nationalgrid



Regional Synchronous Generation

Increasing unequal distribution of synchronous generation across the GB transmission network

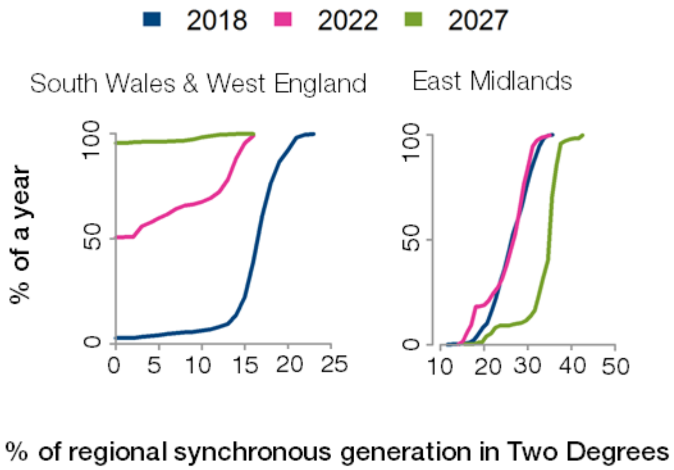


Regional Synchronous Generation

Trend: Absence of synchronous generation in some regions become frequent

Insight: These regions are vulnerable to operability challenges related to low system strength

Actions: Dynamic voltage support is needed in these regions



Key Messages

nationalgrid

Regional

High electricity flows seen in the transmission network in all four seasons

Increasing volatility of electricity flows and frequent low regional synchronous generation

More flexible resources and voltage support will be required

National

Changing in generation mix on the system

The system is becoming less operable without intervention

Transform the industry's approach to operability

We will collaborate with the wider industry to understand how these operability challenges affect their performance

Plan for 2018

nationalgrid

We are working on:

- Enhanced frequency control capability (EFCC) project
- Power potential project
- Phoenix project
- Virtual synchronous machine
- Reactive power roadmap

We will collaborate with:

- TOs and DNOs
- Manufacturers/developers
- Users of the network

to understand the impact of these operability challenges

Questions?

Voltage and Frequency Dependency

Ben Marshall

Technical Specialist

Key Messages

nationalgrid

Today we assess frequency and voltage events separately

In the future we will need to consider combined events

Combined frequency and voltage events occur today

As the levels of synchronous generation decline, this effect will increase

We will work with the energy industry to further develop our regional monitoring and modelling of these combined effects

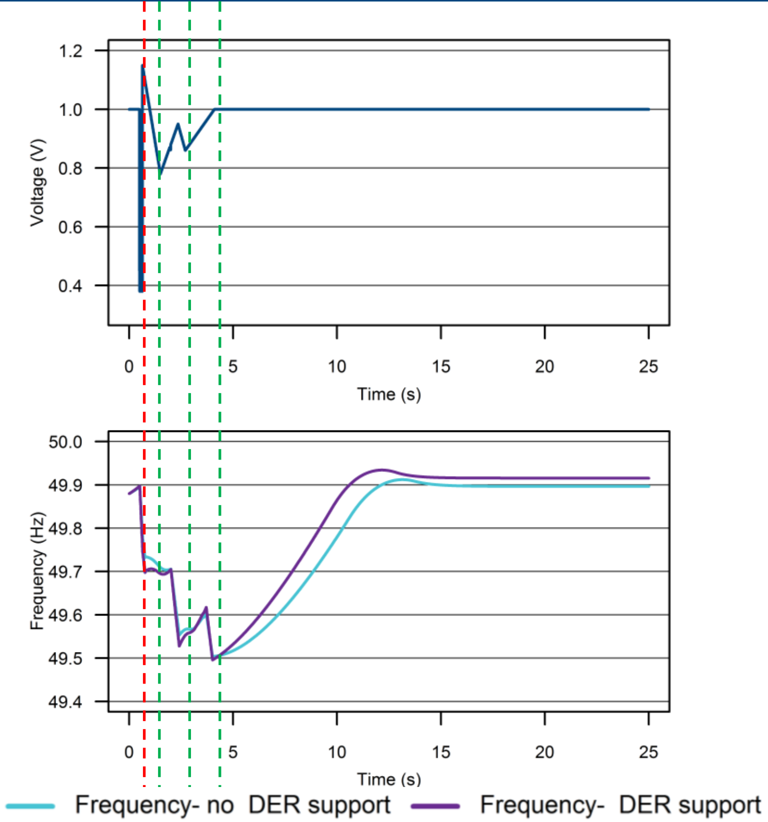
This could provide opportunities for new regional voltage support capabilities

What are frequency and voltage events?

Trend: Higher Non Synchronous Technologies (NST) and changes in demand drive an increasing voltage and frequency dependency

Insight: Regional levels of active power loss need to be limited from National level, unless additional dynamic voltage support found

Actions: We need to inform modelling and increase voltage support resources



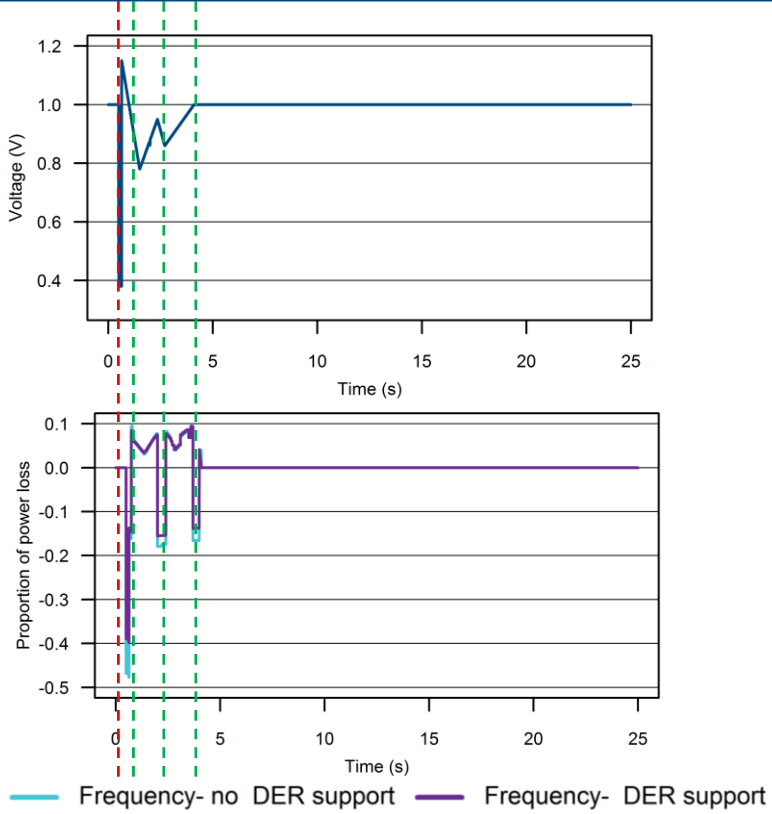
What are frequency and voltage events?

nationalgrid

Trend: Higher Non Synchronous Technologies (NST) and changes in demand drive an increasing voltage and frequency dependency

Insight: Regional levels of active power loss need to be limited from National level, unless additional dynamic voltage support found

Actions: We need to inform modelling and increase voltage support resources

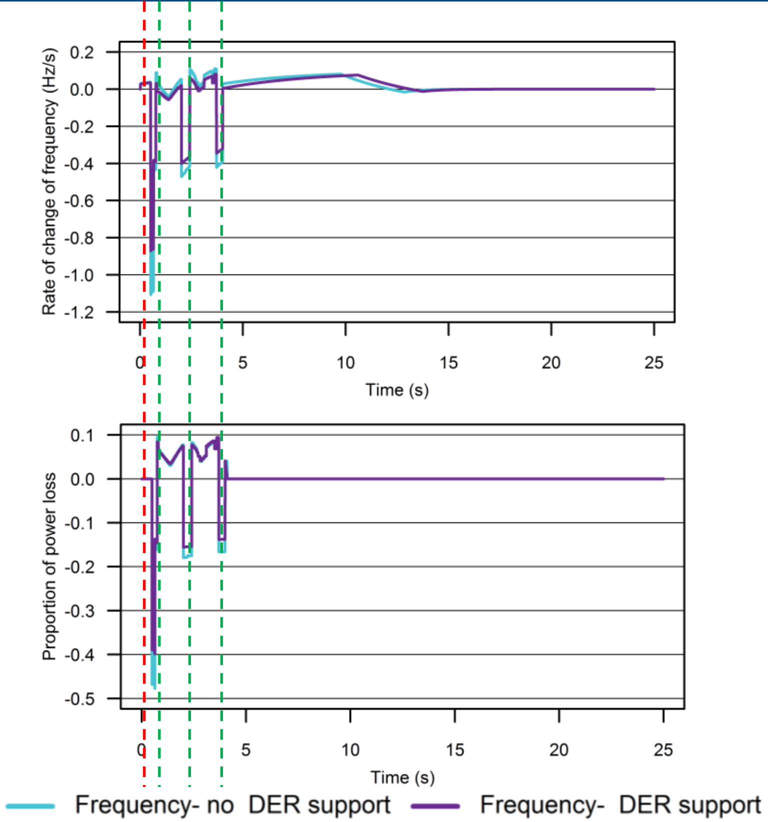


What are frequency and voltage events?

Trend: Higher Non Synchronous Technologies (NST) and changes in demand drive an increasing voltage and frequency dependency

Insight: Regional levels of active power loss need to be limited from National level, unless additional dynamic voltage support found

Actions: We need to inform modelling and increase voltage support resources



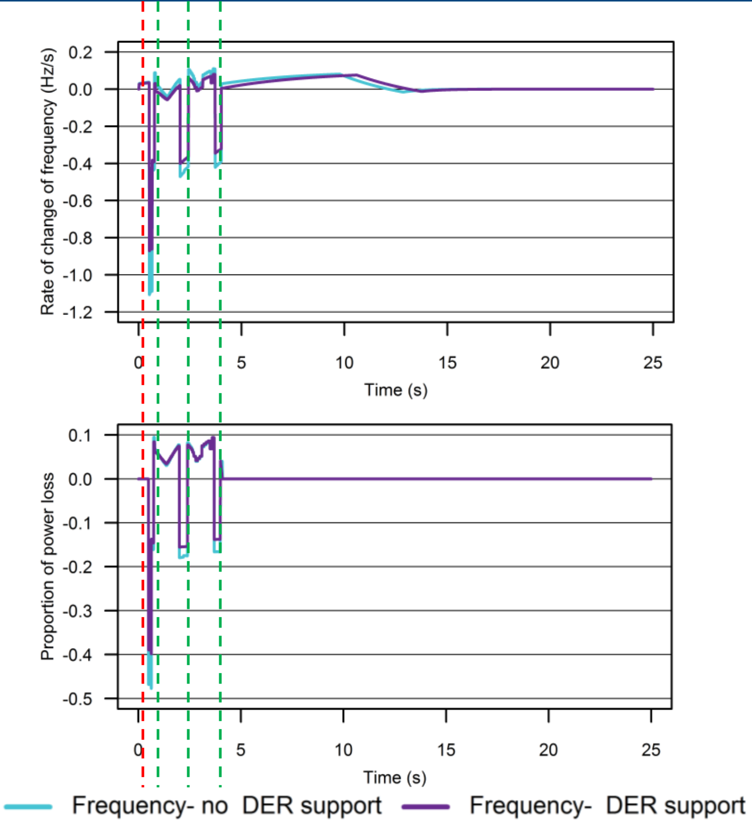
What are frequency and voltage events?

nationalgrid

Trend: Higher Non Synchronous Technologies (NST) and changes in demand drive an increasing voltage and frequency dependency

Insight: Regional levels of active power loss need to be limited from National level, unless additional dynamic voltage support found

Actions: We need to inform modelling and increase voltage support resources



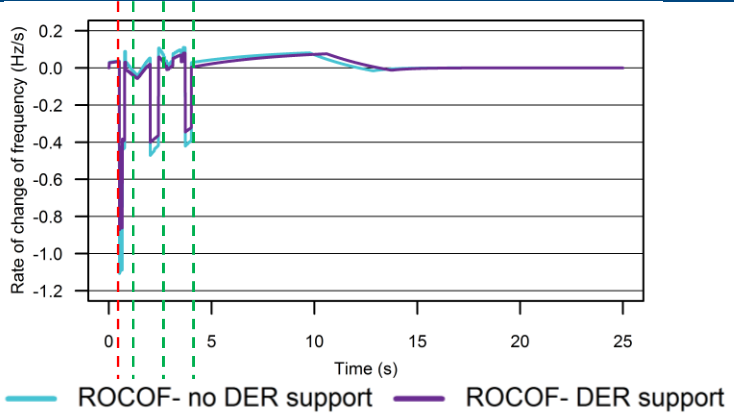
What are frequency and voltage events?

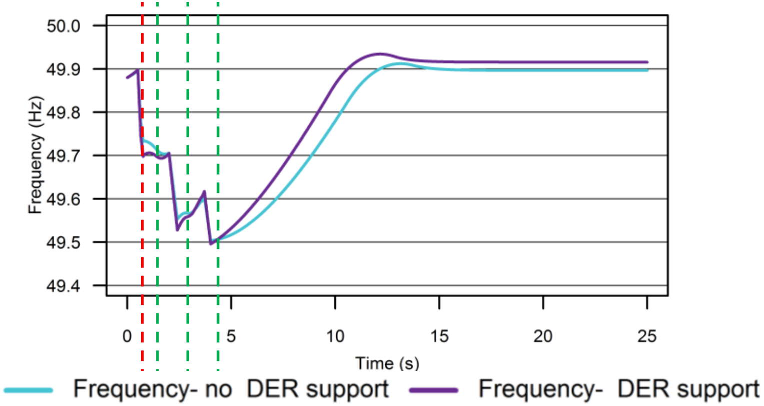
nationalgrid

Trend: Higher Non Synchronous Technologies (NST) and changes in demand drive an increasing voltage and frequency dependency

Insight: Regional levels of active power loss need to be limited from National level, unless additional dynamic voltage support found

Actions: We need to inform modelling and increase voltage support resources





3 Case Study areas considered

nationalgrid

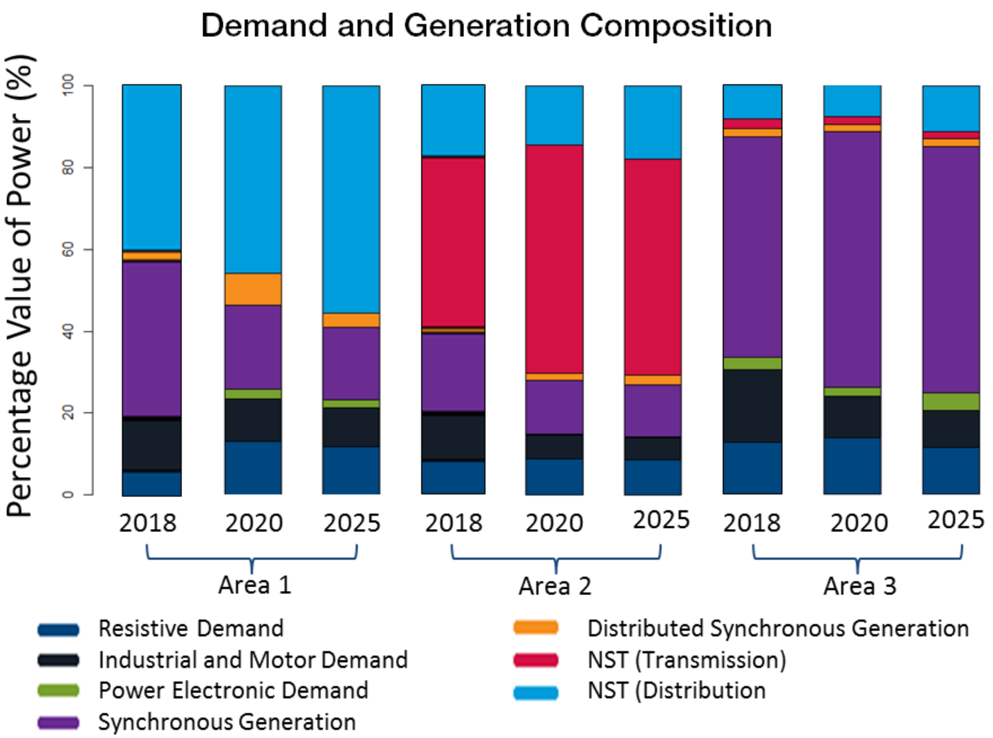
Area 1:
High Non- Synchronous Technology (NST) growth, mainly in distribution system

Area 2:
NST growth greater in transmission system

Area 3:
NST growth balanced by continued synchronous generation developments

Different demand and generation compositions

Different Voltage and Frequency behaviours

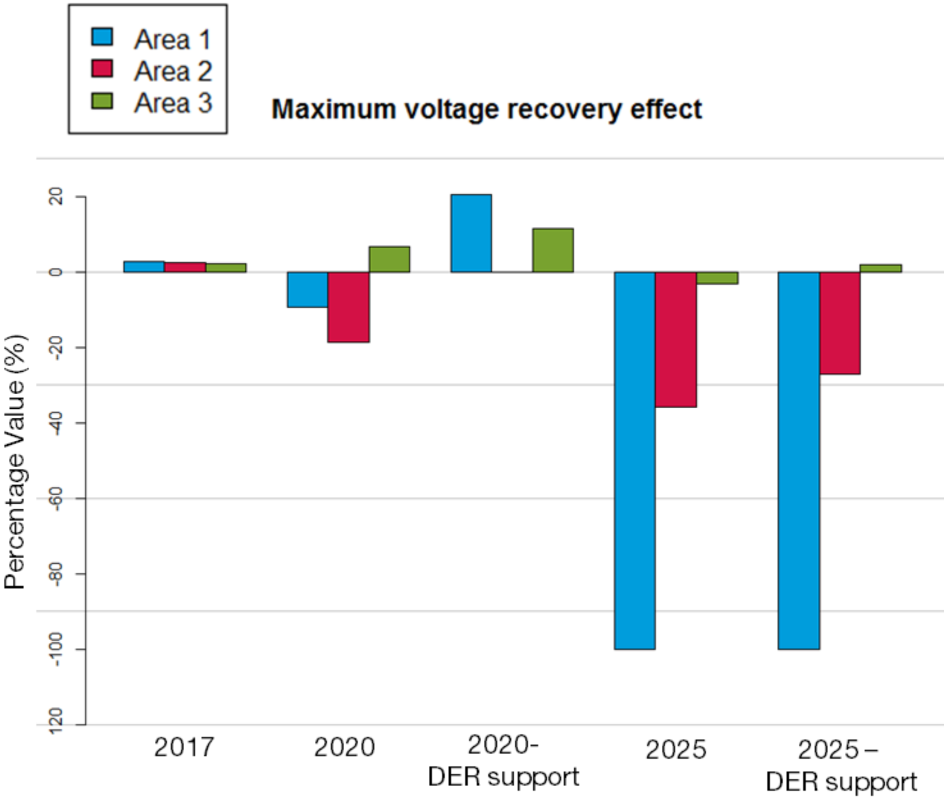


Results

Trend: from a small positive effect today, combined frequency and voltage effects drive a range of larger future regional frequency containment considerations.

Insight: Higher NST penetrations and greater voltage sensitivity in load lead to slower, more oscillatory, voltage recovery. This leads to varied impact on frequency containment by area

Actions: To collaborate across the industry to further develop regional frequency and voltage-sensitive modelling



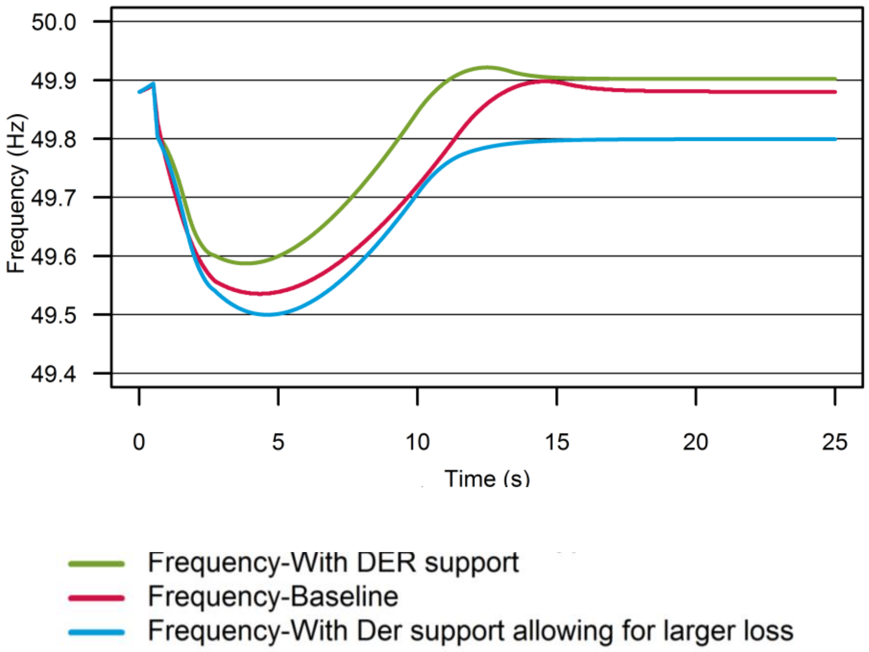
Actions to mitigate: DER support?

nationalgrid

Trend: Distributed Energy Resources (DER) are increasing

Insight: DER support can mitigate combined frequency and voltage effects as DER grows over time

Actions: We need to continue to engage across the industry to deploy and specify the capabilities of DER most effectively



Next steps

nationalgrid

We have provided an example of how Trends and Insights inform further operability assessment

We intend to publish further information on our findings within our Assessment Report, in Spring 2018

We will explore opportunities for industry collaboration in advancing understanding and response to this operability area

Where does this effect come from?

Why does it change?

How does it change?

Key Messages

Today we assess frequency and voltage events separately

In the future we will need to consider combined events

Combined frequency and voltage events occur today

As the levels of synchronous generation decline, this effect will increase

We will work with the energy industry to further develop our regional monitoring and modelling of these combined effects

This could provide opportunities for new regional voltage support capabilities

Questions?

Trading Trends & Real Time Example

Paul Rowe-Jones
Energy Trader

Contents

nationalgrid

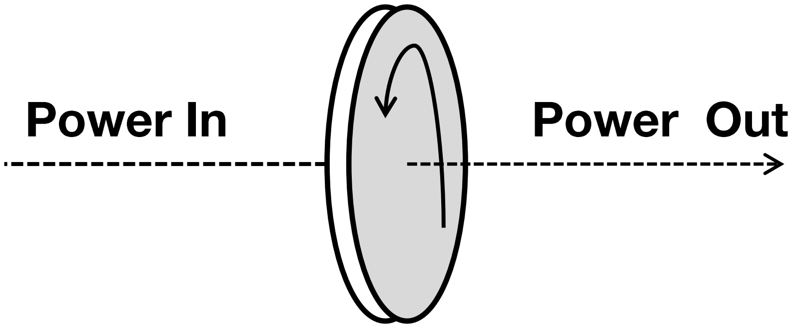
- Overview of the actions SO must take to ensure grid security
- Review of 2017 SO trading trends
- Where are we going?

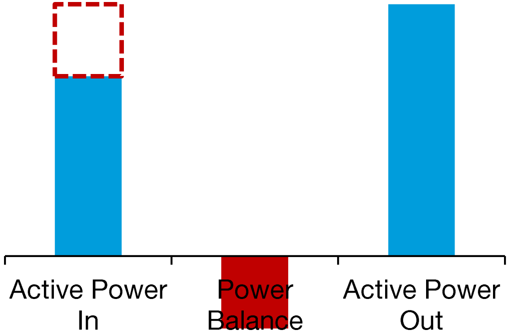
System Needs

Frequency and Rate of Change of Frequency (RoCoF)

nationalgrid

- The SO must manage the Network to keep frequency within statutory limits
- For a 'Normal' loss: 50 ± 0.5 Hz
- A significant volume of embedded generation uses protection which will disconnect the generator if RoCoF > 0.125 Hz/s
- The consequent generation loss can amplify the initial loss, leading to a greater frequency deviation
- The SO must manage Largest Losses, Inertia and Response Holding



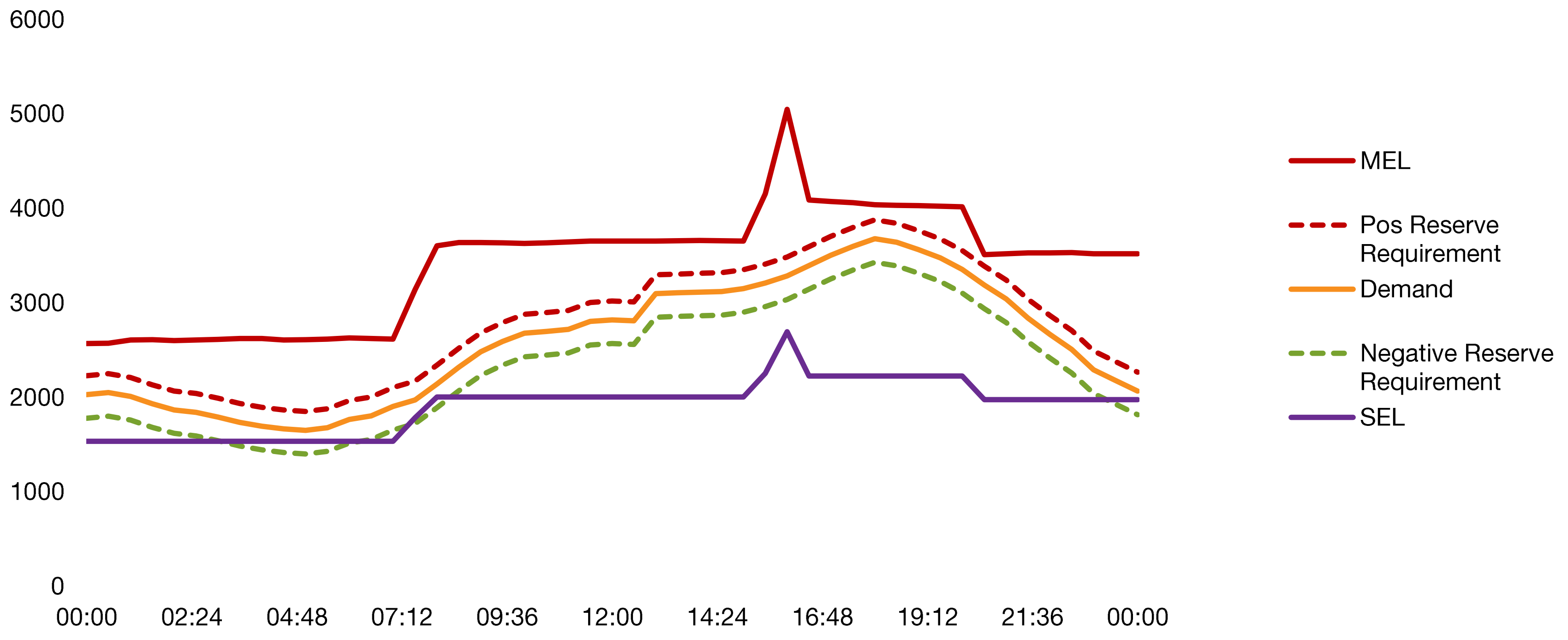


Reserves

- Market imbalance and unexpected losses of Generation/Demand must be replaced in real time

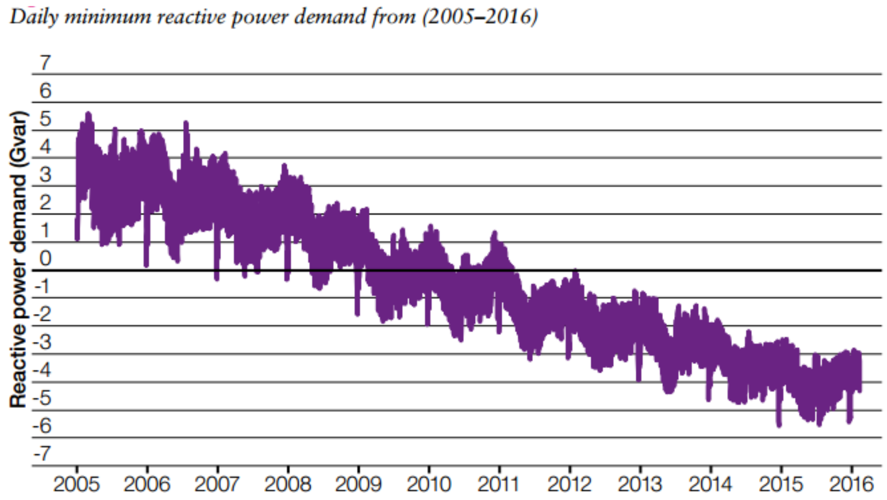
- The SO must ensure that sufficient ‘flexibility’ is available to manage imbalance and credible losses
  - Upwards Reserve (‘margin’) is the ability to increase the output of generators in short timescales
  - Downwards Reserve (‘footroom’) is the ability to decrease that output

Reserve Model



Voltage

- The SO must keep within:
  - Steady State Limits
  - Step Change limits
- Load is becoming more capacitive
- This is leading to high volts and increasing the need for MVAr absorption
- Voltage Requirements are locational
- After 'Transmission' options have been used, a minimum voltage generation requirement remains



Interactions

- The SO must meet each of these requirements simultaneously and at all times
- However, actions taken to resolve one constraint may exacerbate another
- These interactions are particularly acute at low demand

Interactions

	Downward Reserve	Positive Reserve	Response Availability/Requirement	RoCoF	Voltage
Desynch Machine	Improves	Worsens	Worsens	Worsens	Worsens
Synch Machine	Worsens	Improves	Improves	Improves	Improves
Reduce Storage / IC/ DER Imports	Improves	Worsens	Improves (if IC is LL)	Improves (if IC is LL)	-
Increase Storage / IC/ DER imports	Worsens	Improves	Worsens (if IC is LL)	Worsens (if IC is LL)	-
Position Plant for Response	Worsens	Worsens	Improves	-	-

RoCoF: Rate of Change of Frequency

IC: Interconnector

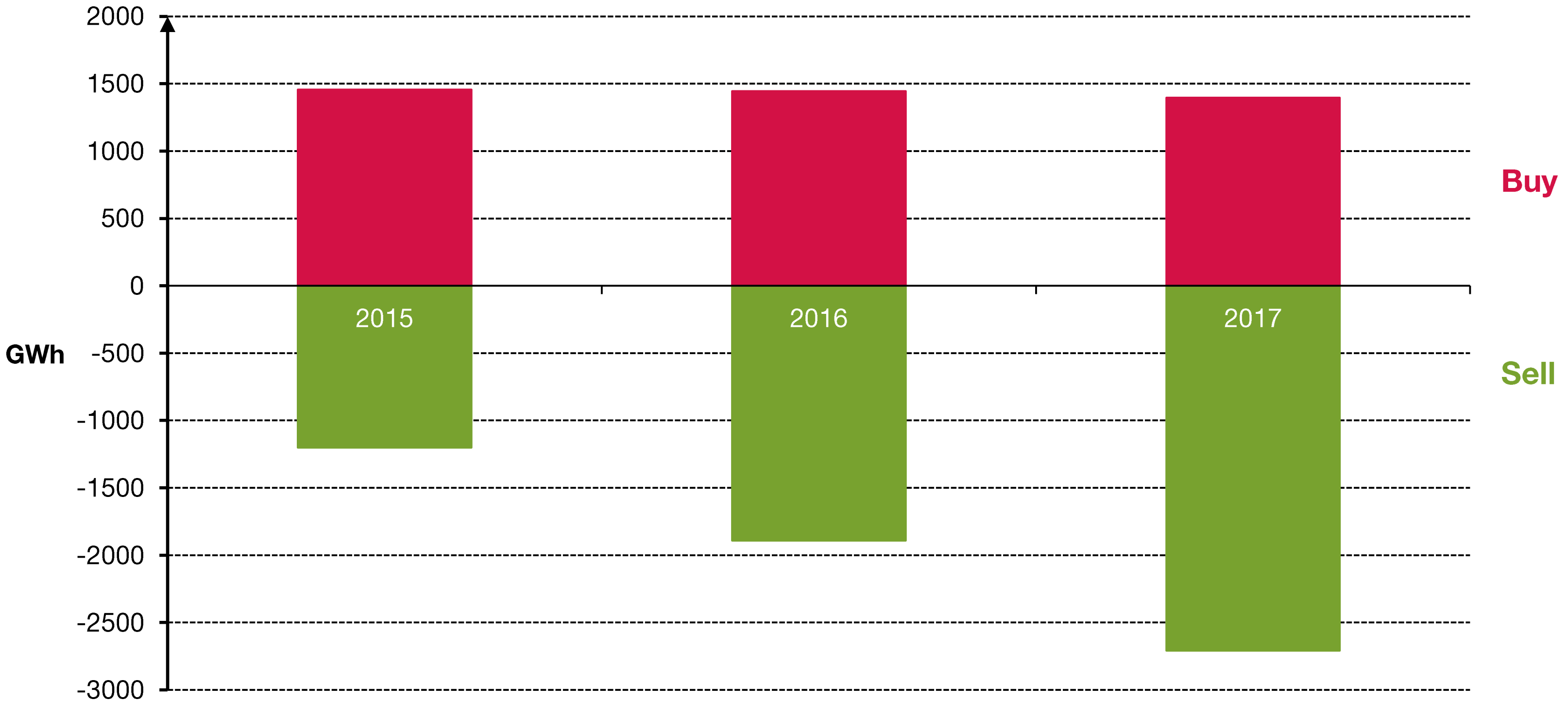
LL: Largest Loss

Review of 2017 Trading Activity

Role of the Trading Team

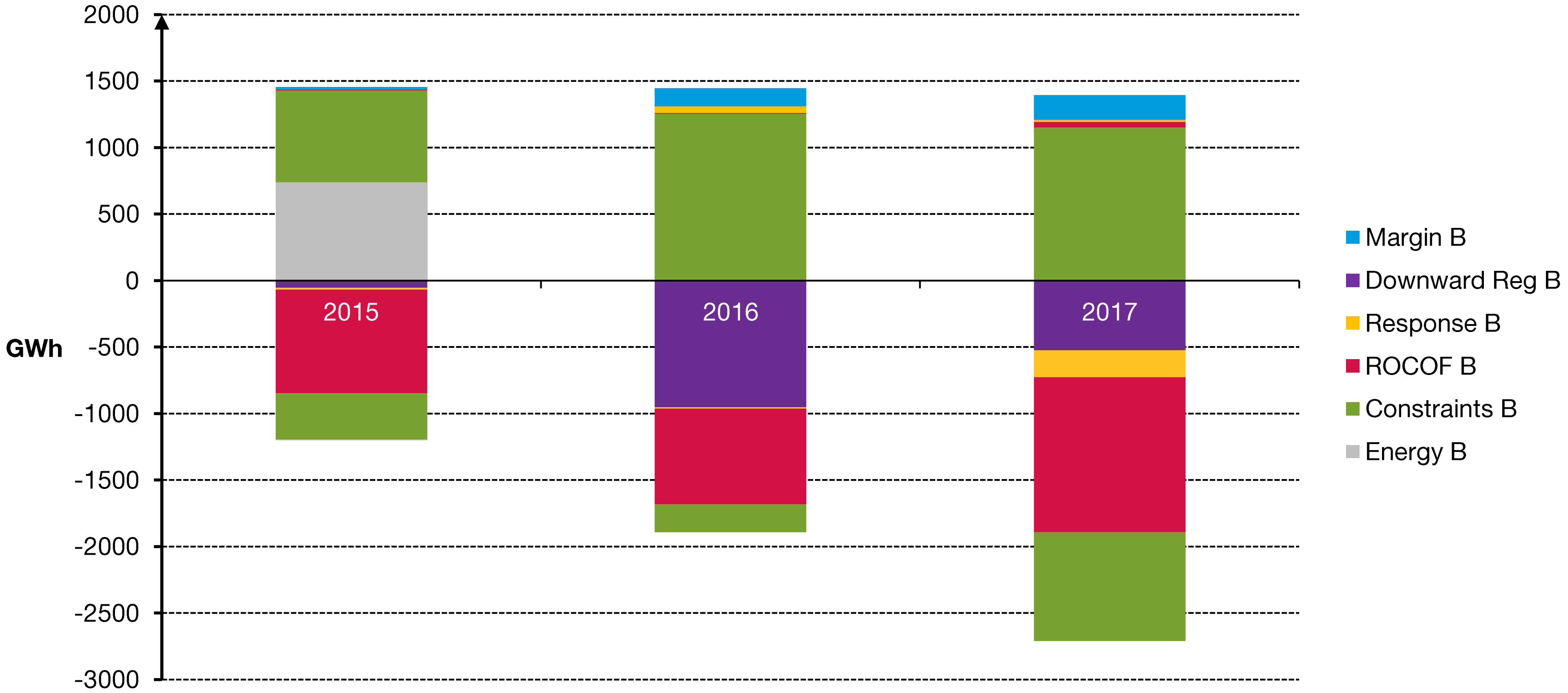
- The trading aim to take actions via forward trades where more economic than post gate closure alternatives
- Tenders are cast as wide as possible to fill a system need
- Trades are conditional on delivery on a particular unit

Volumes



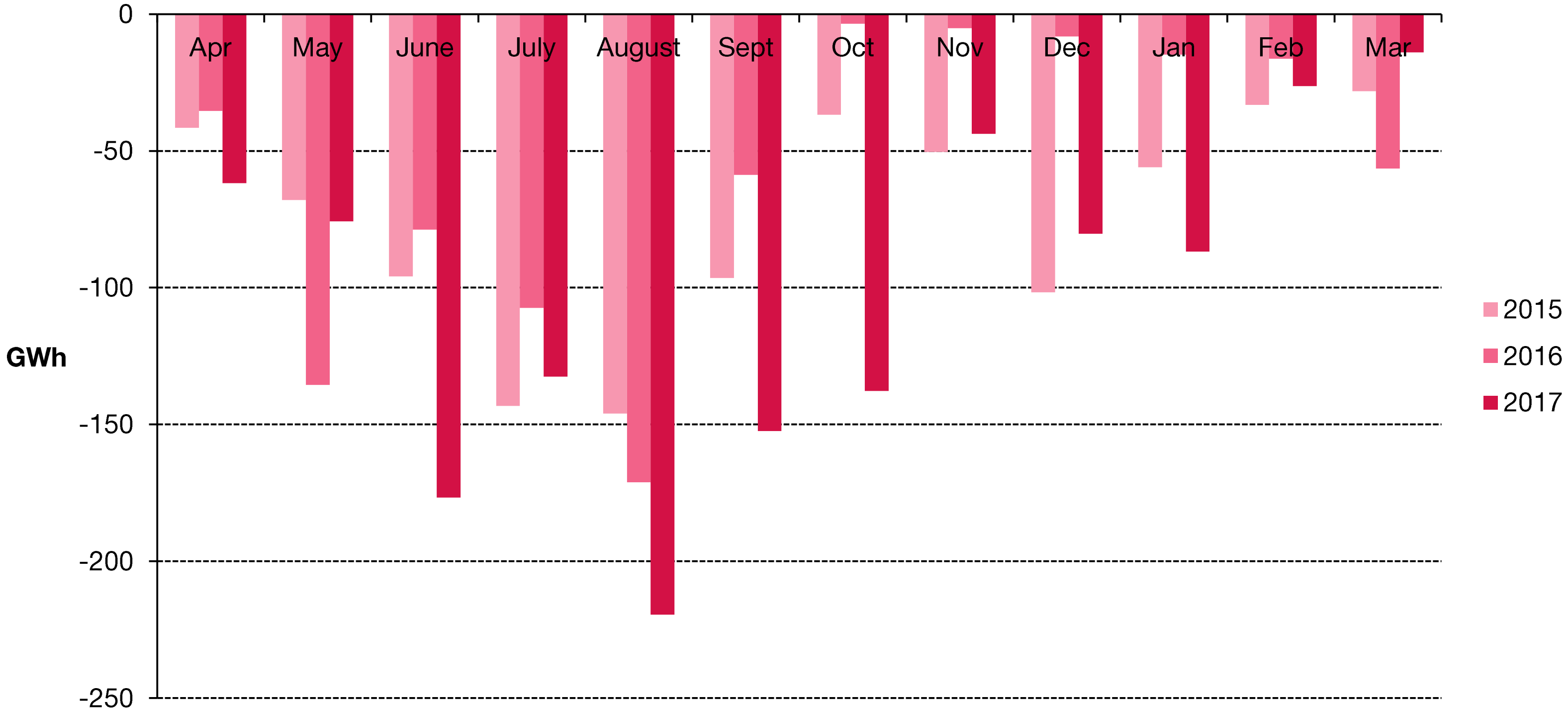
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
GWh
2015
2016
2017
Buy
Sell

Reasons

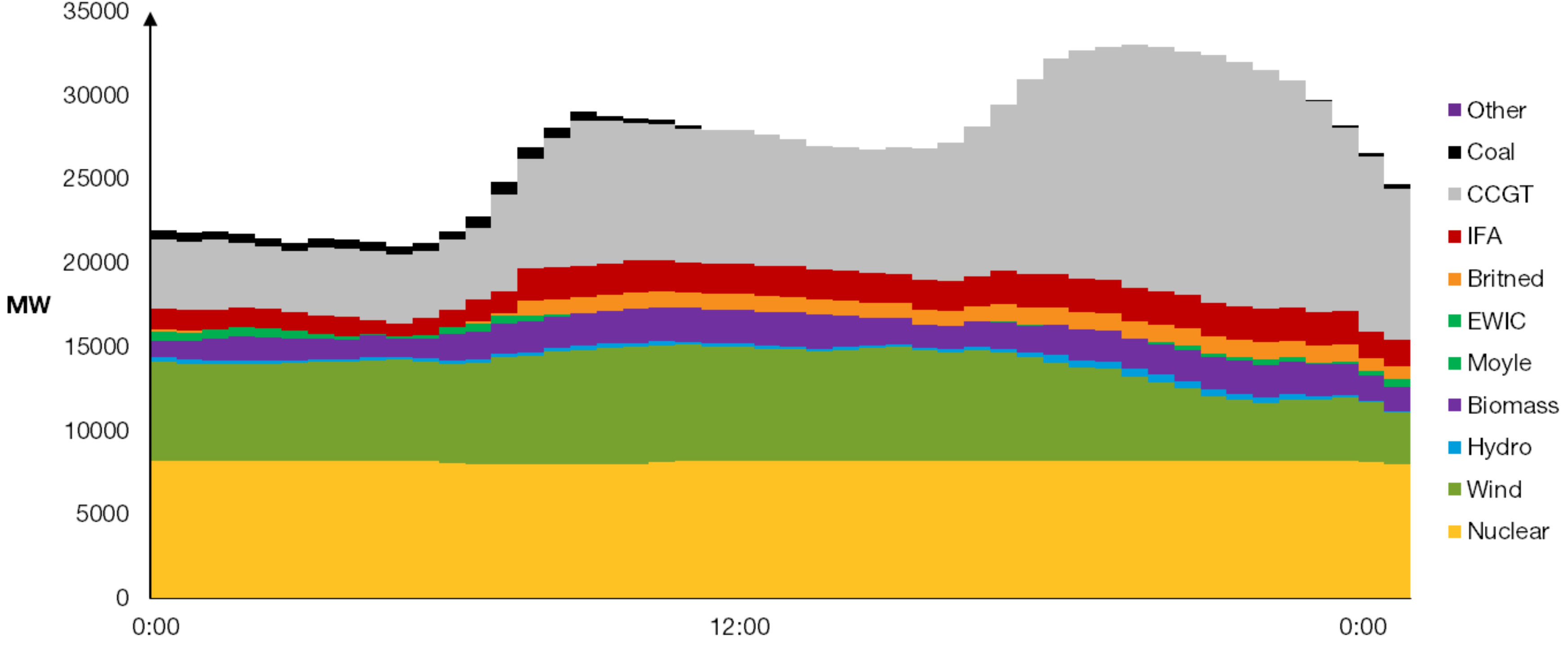


2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
GWh
2015
2016
2017
Margin B
Downward Reg B
Response B
ROCOF B
Constraints B
Energy B

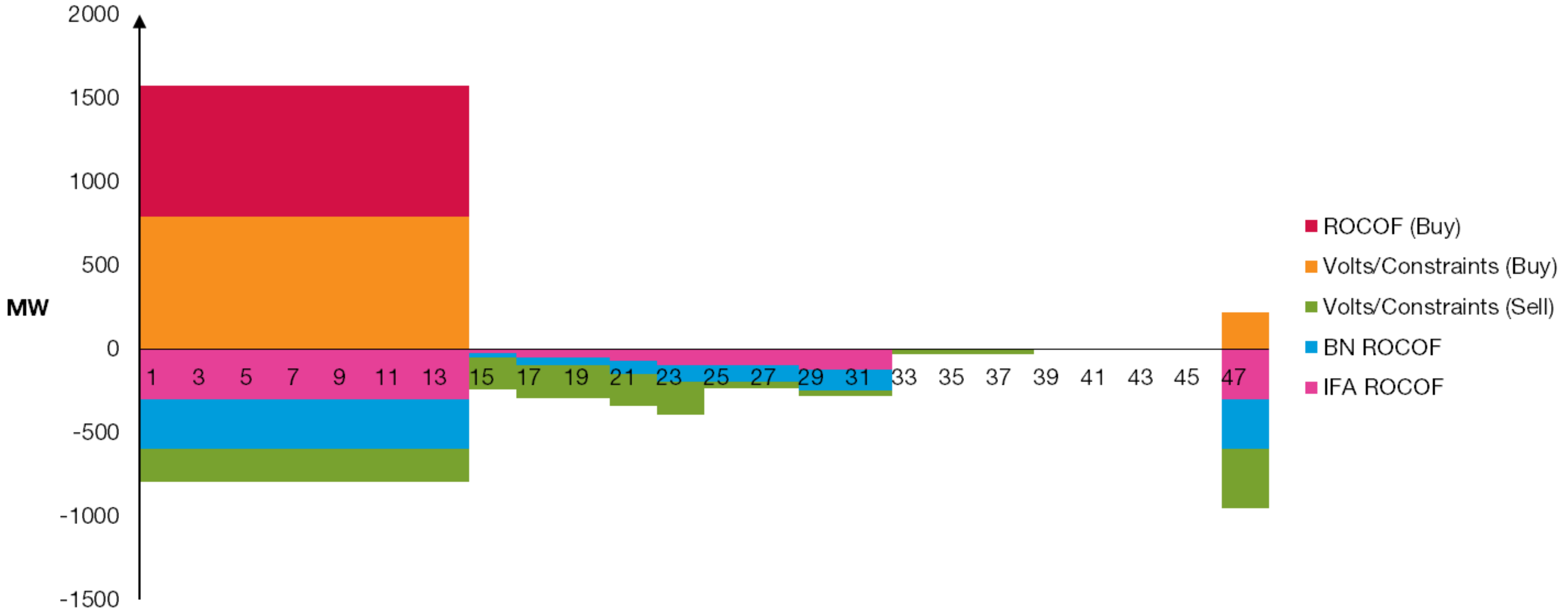
ROCOF by Month



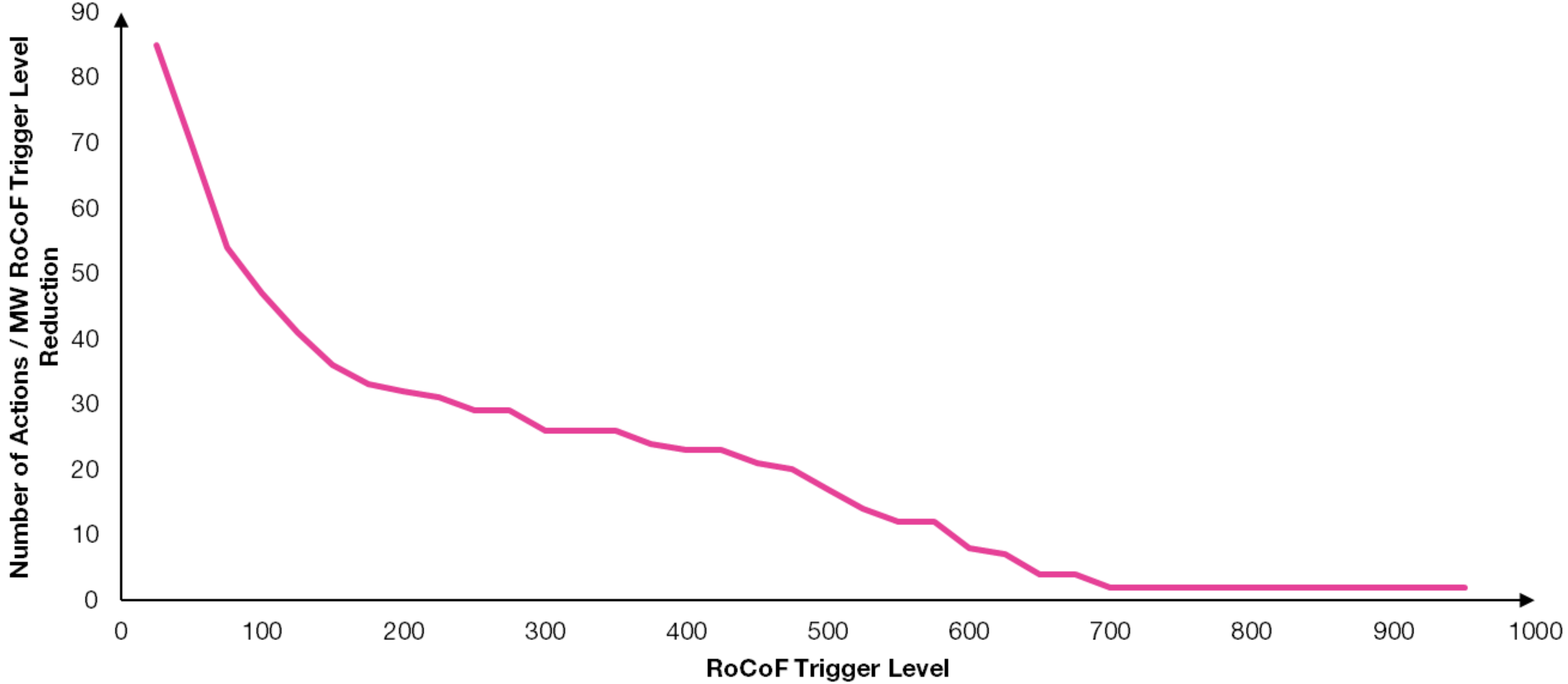
7th June 2017



7th June 2017



7th June 2017



Where next?

nationalgrid

- With decreasing transmission system demand we expect system inertia to continue to fall
- This will mean more periods where the SO takes actions to manage largest losses
- Reducing largest losses is only viable up to a point – after which inertia must be increased by synchronising machines
- The interaction between reserve requirements and response holding becomes more onerous at low inertia
- This should drive the need for new sources of reserve

https://www.nationalgrid.com/uk/electricity/balancing-services/future-balancing-services

Questions?

Future of Balancing Services Product Roadmap: Response & Reserve

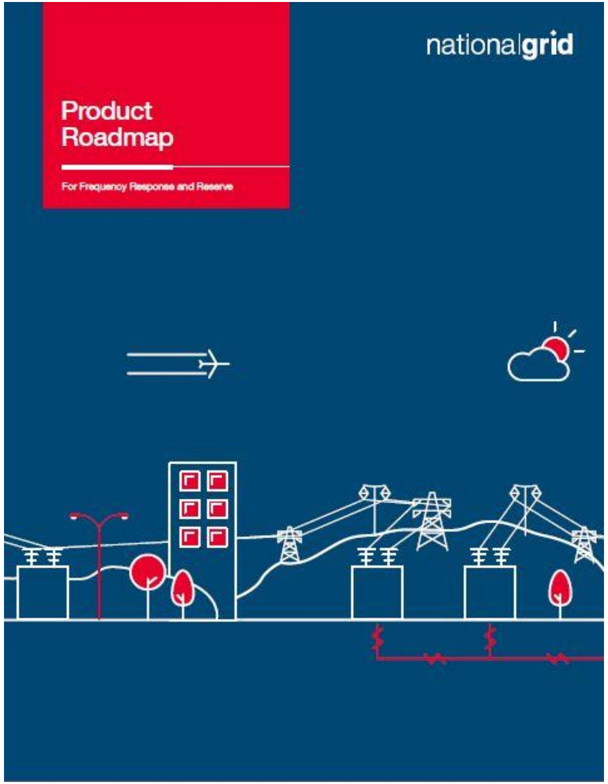
Adam Sims
SO Flexibility Manager

Content

Principles

Frequency Response

Reserve



Principles – Summary of Consultation

- Majority of market participants prefer a standardised approach to the specification of product
- A mix of both short-term markets and the periodic longer-term contracts was favoured by 62% of respondents
- 68.4% of respondents were positive or very positive about trialling alternative procurement approaches
- Other themes from consultation include transparency of SO's day-to-day activities and reducing barriers to entry

Principles

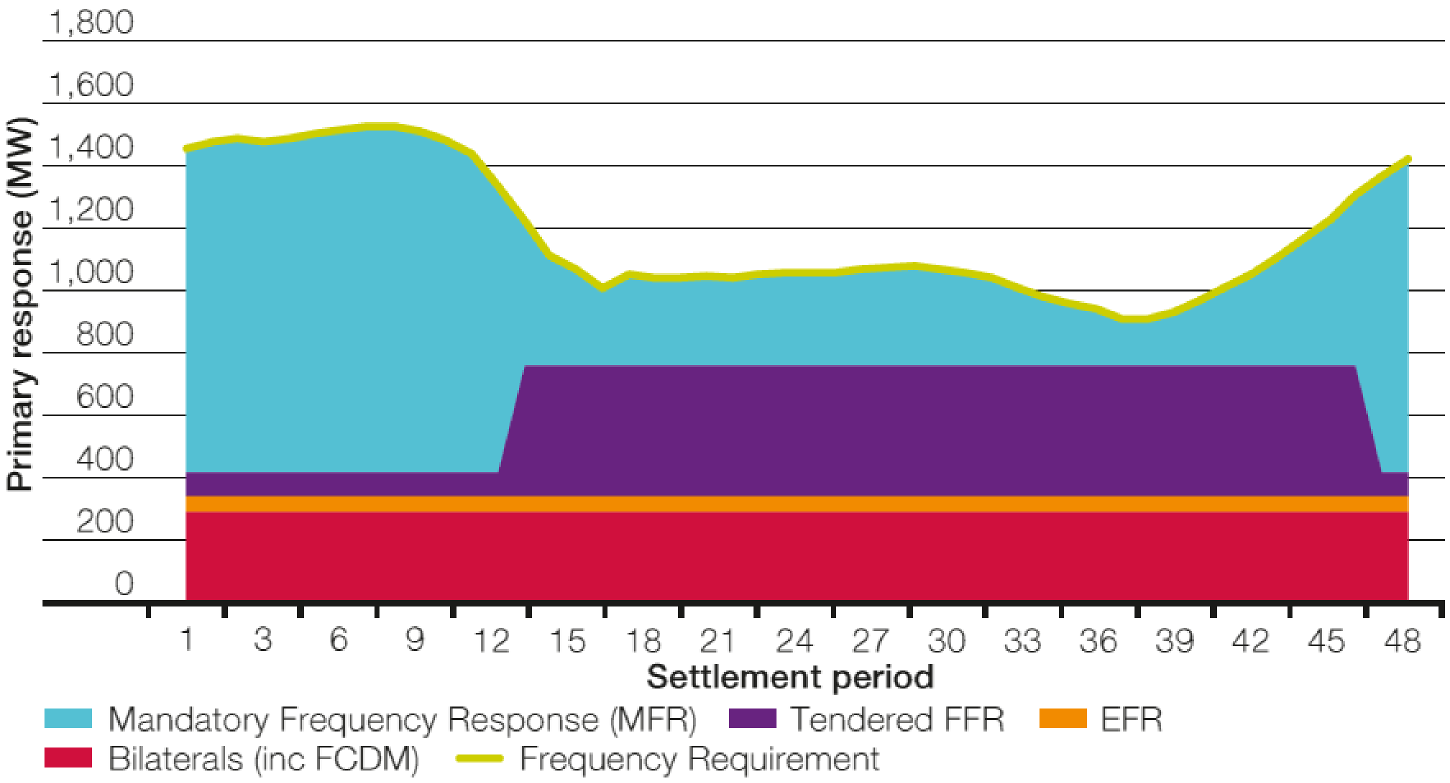
nationalgrid

Our procurement decisions will be transparent and our methodology and needs will be clear to the market ahead of time

The design of our products, the way we procure, and the contractual arrangements will increase competition in provision of services to the SO

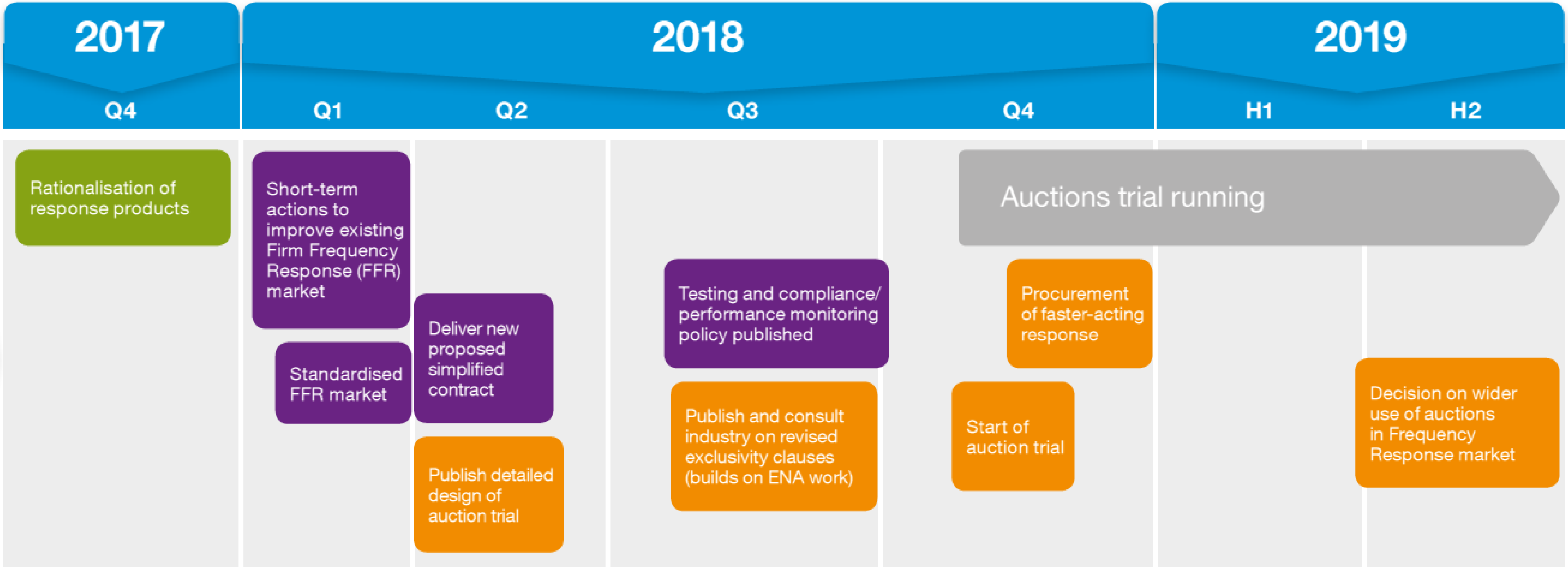
Our products will be designed to balance both operational requirements and the technical ability of provider assets while maintaining system security

Frequency Response - Today



Frequency Response - Roadmap

nationalgrid



Frequency Response - Simplification

nationalgrid

Illustration 1

Jan to March – When tendering between January and March, you can tender for the front month +

Q1

Summer 18	Winter 18	Summer 19	Winter 19	Summer 20

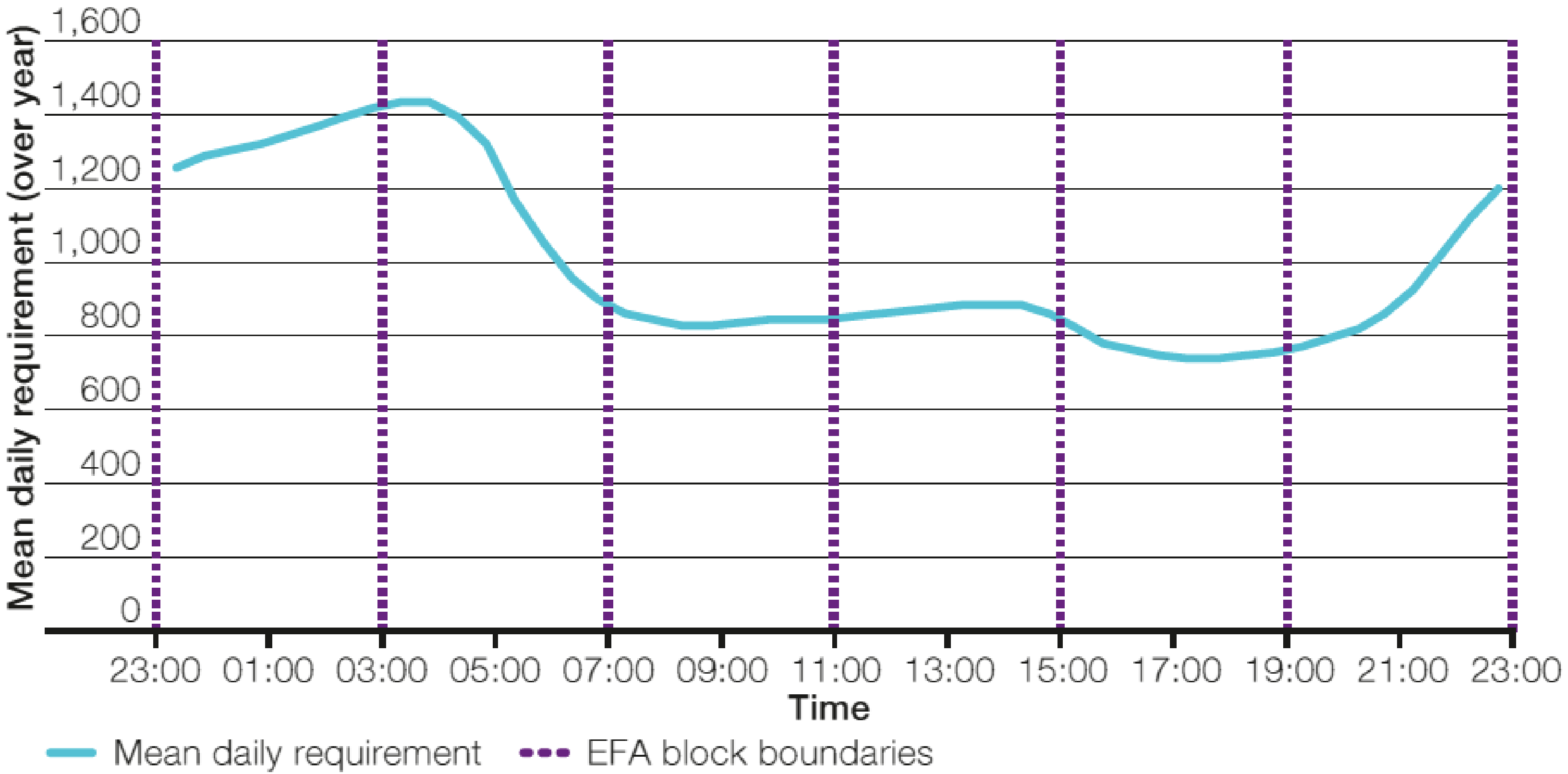
Illustration 2

April to June – when tendering within Q1, i.e. April to June, then, you can tender for the front month +

Q2

Winter 18	Summer 19	Winter 19	Summer 20

Frequency Response - Simplification



Frequency Response - Improvement

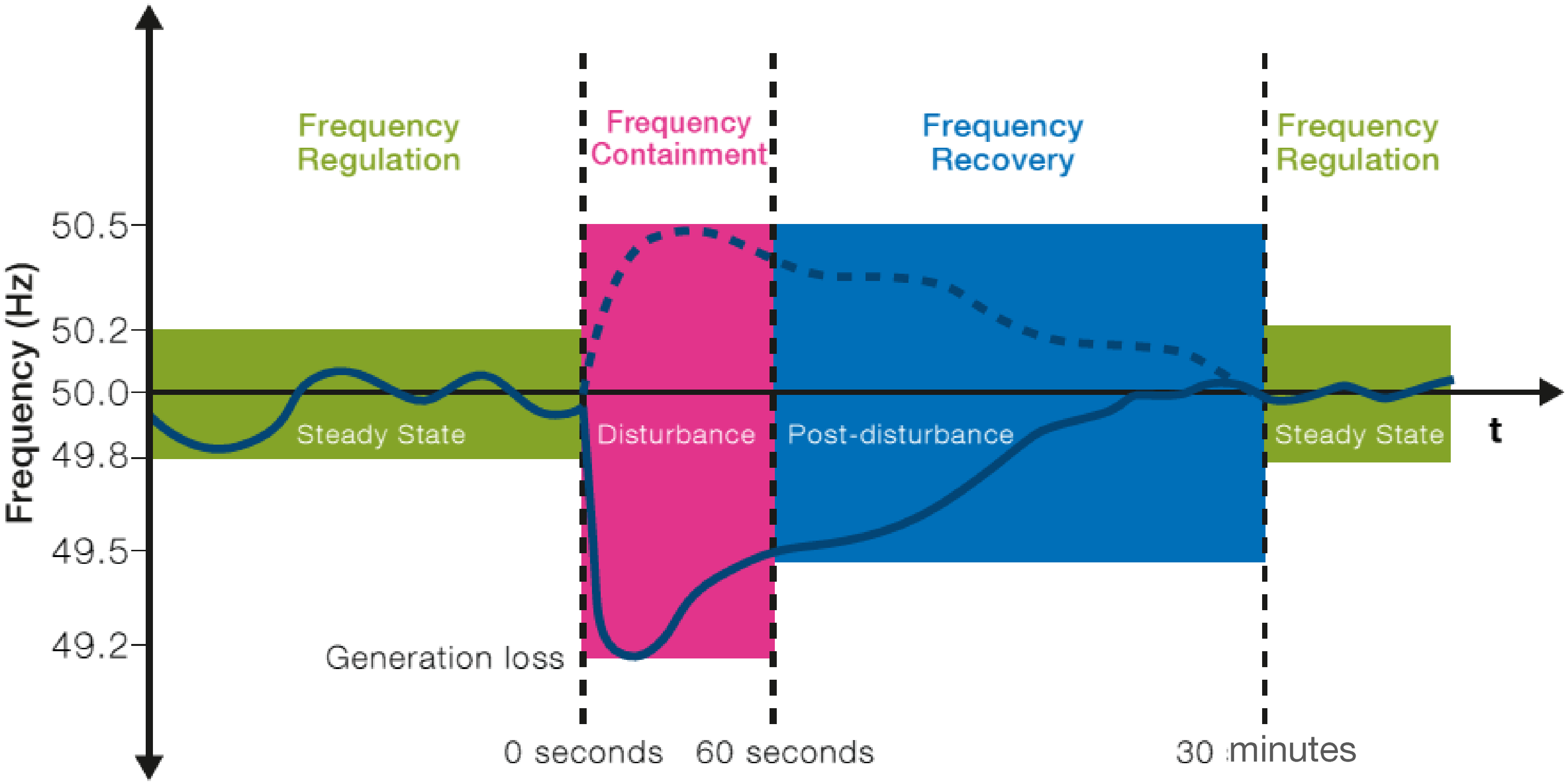
nationalgrid

- Trial of closer to real time procurement
  - Weekly cleared price auction
  - 12 month trial starting end of 2018

- Benefits
  - Industry: more flexible, transparent, simpler
  - SO: more competitive, automated

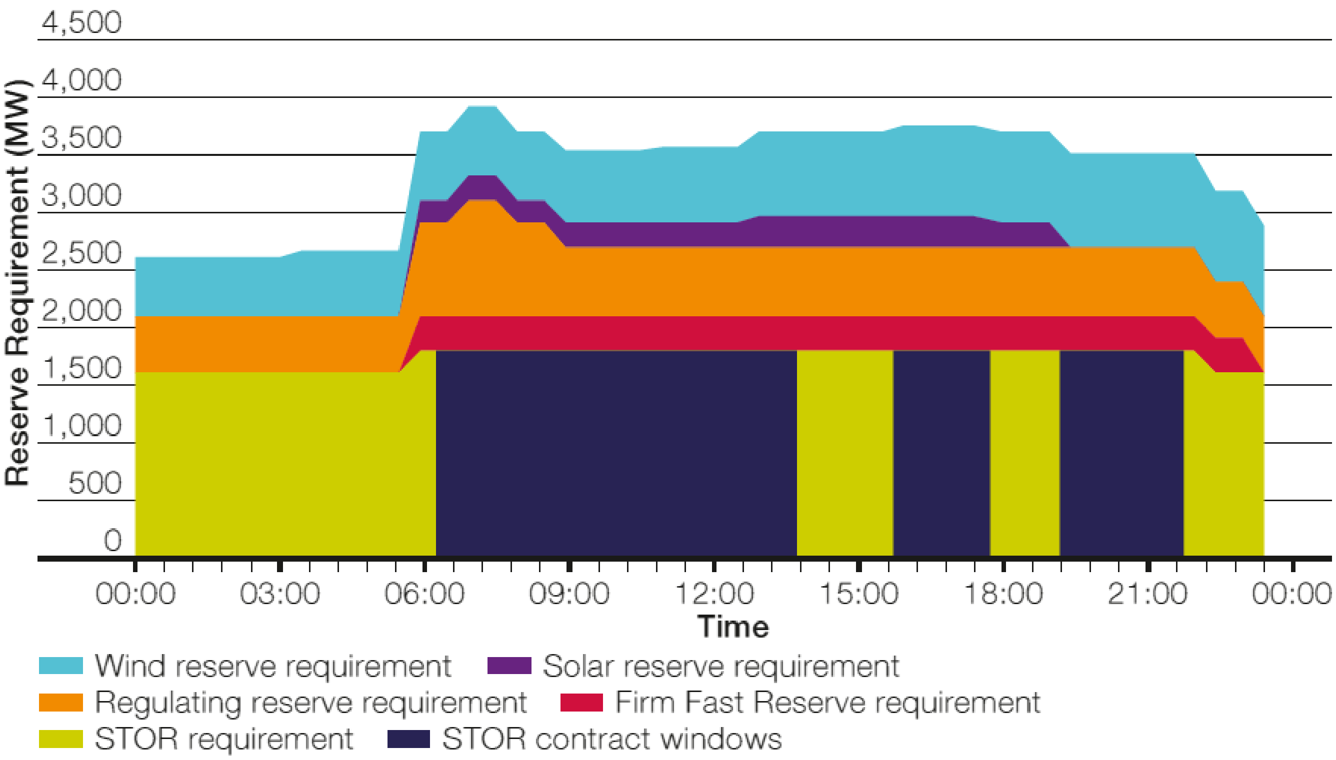
Frequency Response – Fast Response

nationalgrid



Reserve - Today

Illustration of typical Operating Reserve Requirement components



Reserve - Roadmap

nationalgrid

2017

Q4

- Rationalisation of reserve products

2018

Q2

- Standardised products in STOR and Fast Reserve implemented

Q3

- Deliver Phase 1[1] of Platform for Ancillary Services (PAS) project[2] – roll out for Fast Reserve providers
- Deliver new proposed simplified contract
- Testing and compliance/ performance monitoring policy published
- Publish and consult industry on revised exclusivity clauses (builds on ENA work)

Q4

- Deliver Phase 2[3] of PAS project – roll out for STOR providers

2019

H1

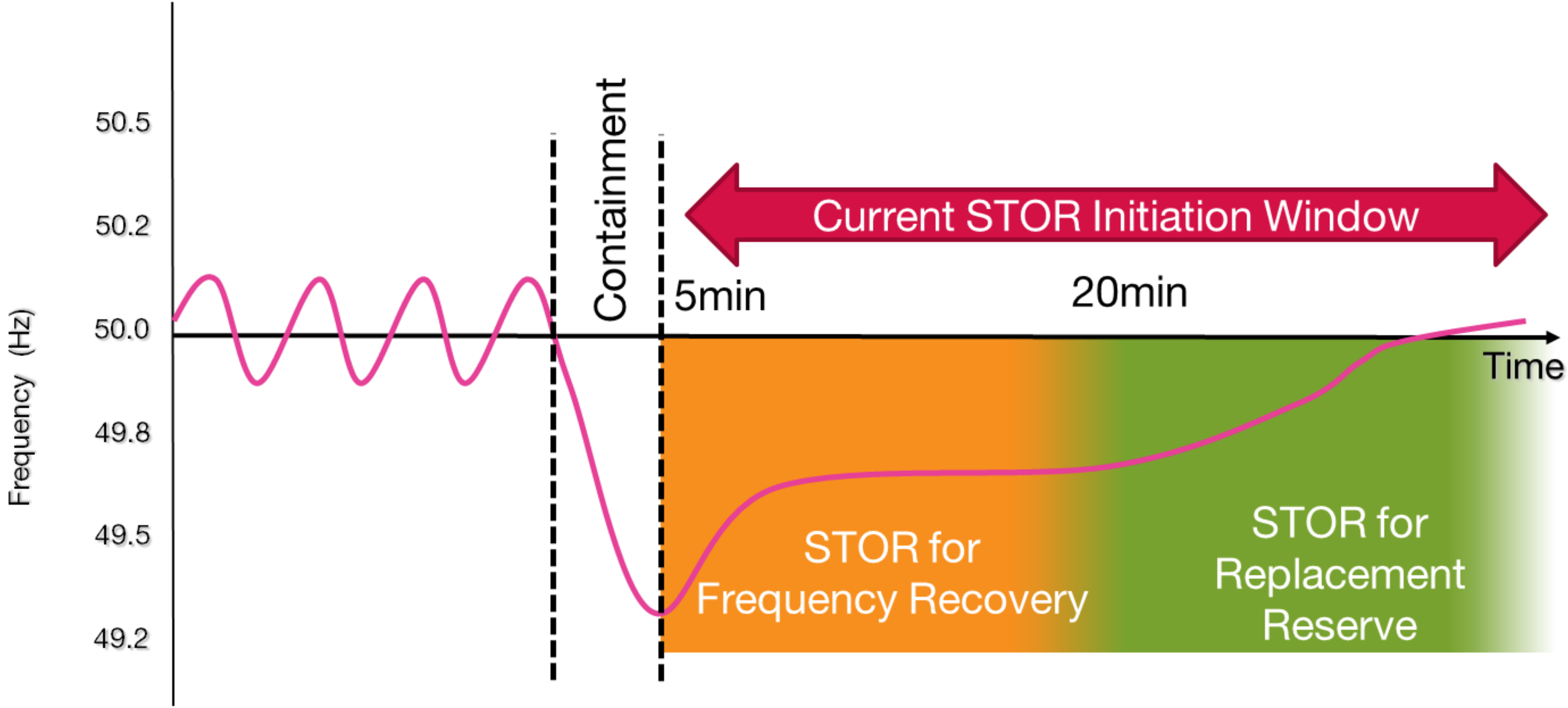
H2

- Decision on wider use of auctions in reserve markets following FFR trial
- Implementation of TERRE[4]

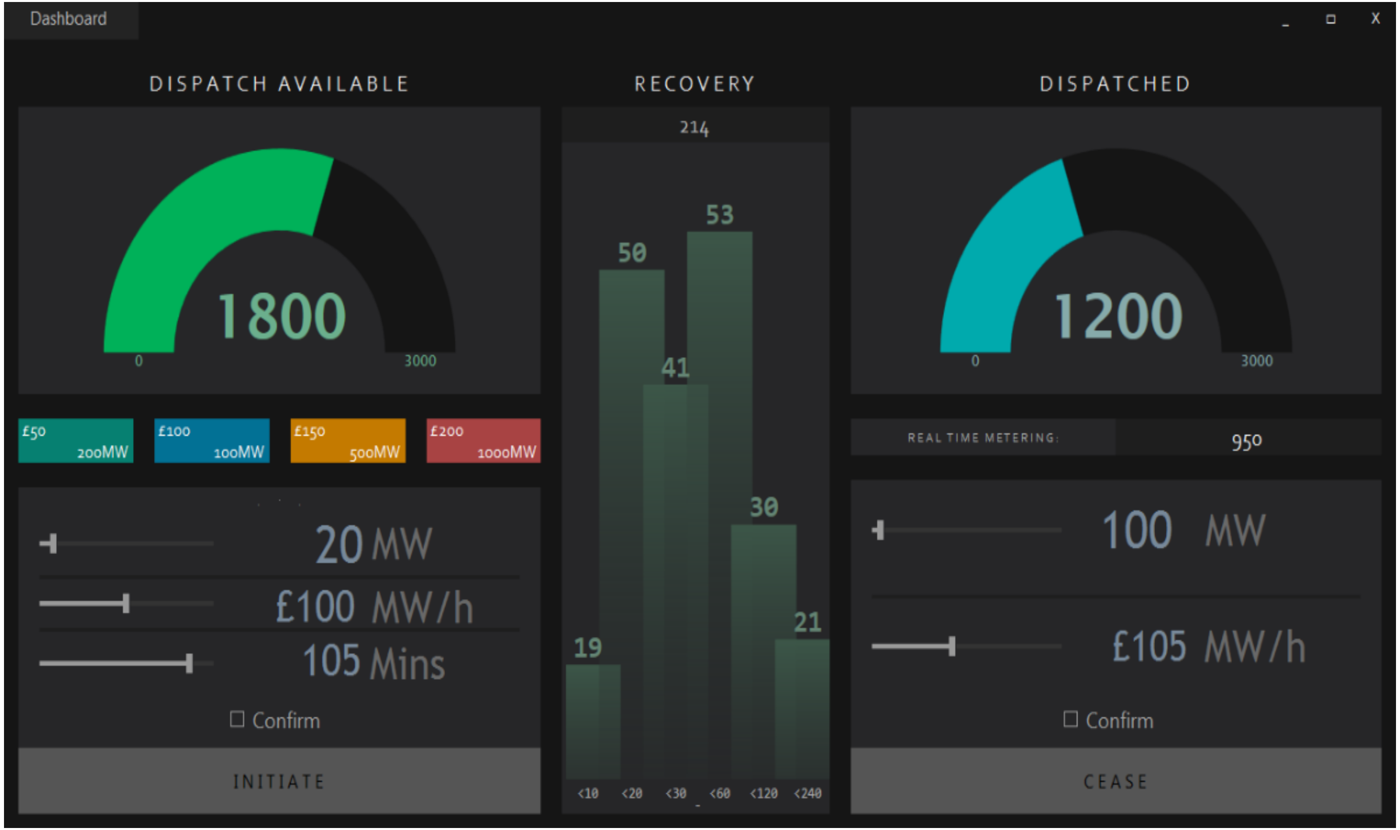
2021

- Implementation of MARI[5]

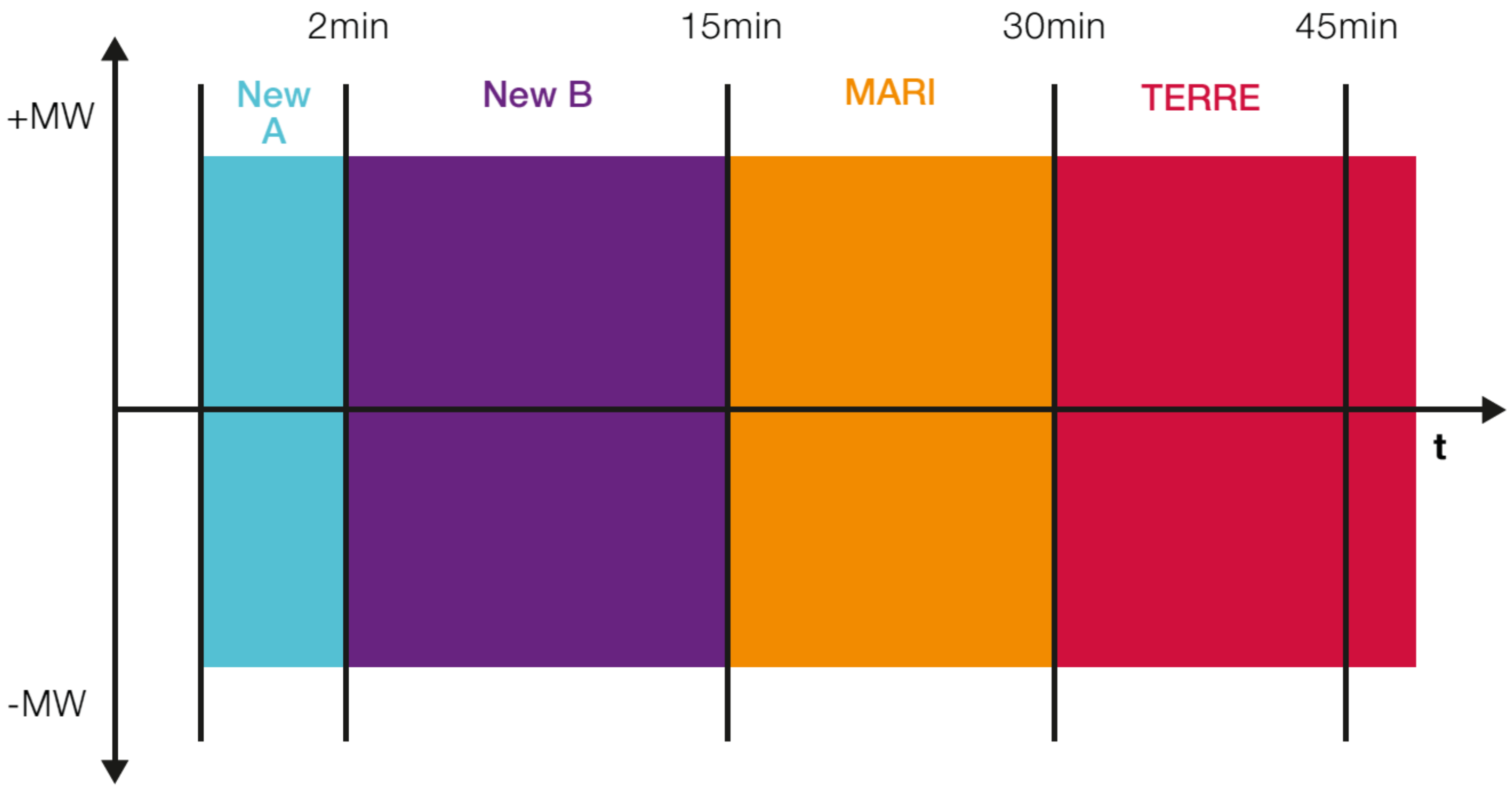
Reserve - Simplification



Reserve – Platform for Ancillary Services



Reserve – Standard Products



Questions?

nationalgrid

Plan for Afternoon

Market Stalls

nationalgrid

Stall 1: SOF publications

Come and talk to us about SOF publications. You can find out more about our past and current assessments. You can also speak to Gas Future Operability Planning team to understand what interaction we expect between future gas & electricity operability.

Stall 2: Phase locked-loop controllers (PLL)

Come and talk to us about our recent assessment of phase locked-loop controllers. You can view our PSCAD model, learn more about our plan and how you can get involved.

Stall 3: Find out about SO innovation

Come and talk to us about the system operator's innovation strategy and projects.

Stall 7: Future of balancing services

Come and talk to us about our future services roadmaps.

Stall 6: Fault levels

Come and talk to us about the impact of declining fault levels on the whole system. Learn more about our plan to investigate the impact on network owners and users of the transmission system. Find out how you can get involved.

Stall 4: Ongoing codes developments

Come and talk to us about latest work on industry codes.

Stall 5: Your views on SOF

Come and tell us about how can we help you get more out of SOF?

Give us feedback on what you find useful in SOF?

Tell us about what we operability issues we should be looking at?