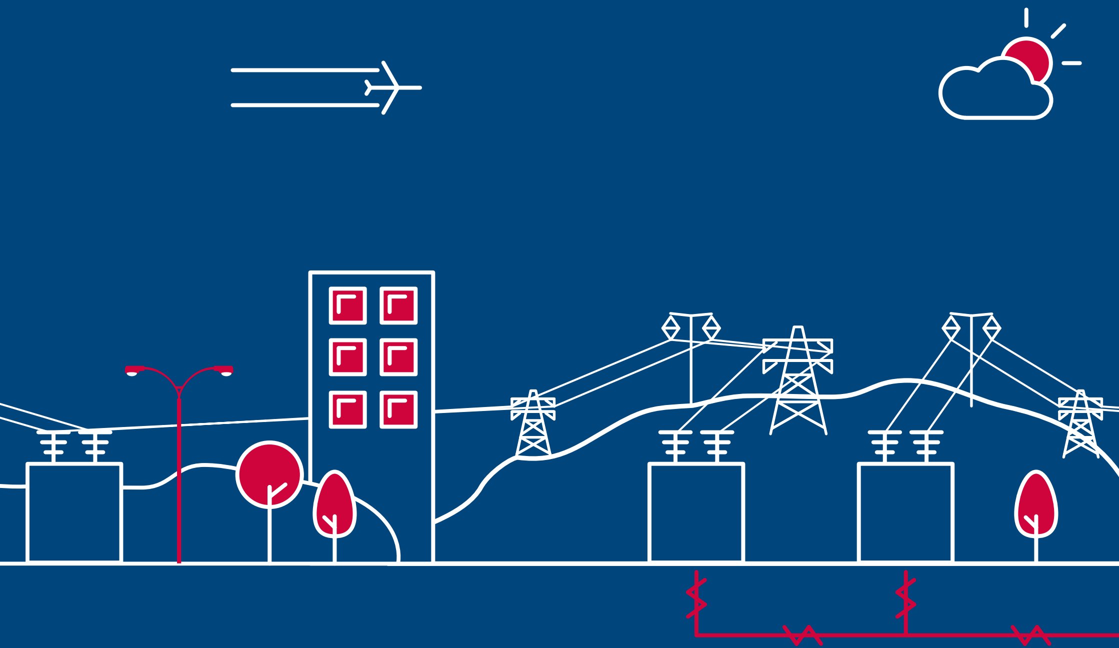
nationalgrid

System Needs and Product Strategy

UK electricity transmission



June 2017

How to use this interactive document

To help you find the information you need quickly and easily we have published *System Needs and Product Strategy* as an interactive document.

Home
This will take you to the contents page. You can click on the titles to navigate to a section.

Arrows
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Hyperlinks
Hyperlinks are highlighted in bold throughout the report. You can click on them to access further information.

Foreword

As the UK transitions to a low carbon economy, it brings changes to the way we operate the electricity system.

We are moving away from a historical reliance on large thermal power generation and there is now a greater diversity of supply and flexible demand than ever before.

The System Operator (SO) has an important role to play in facilitating the transition to a smart, flexible energy system. We are changing to meet the evolving needs of the energy market, while consistently delivering improvements in consumer value. System operation will continue to become ever more sophisticated and complex. We are identifying robust, cost-effective and innovative solutions that will support a secure, low carbon future as economically and efficiently as possible.

We are working with industry to deliver the right solutions at the right time; improving transparency of our needs and developing solutions to maximise the use of all available assets (network, generation and demand) for the benefit of the end consumer.

Our aim is to create balancing services markets that meet our changing system needs and in which all technology types can compete on a level playing field. To achieve this we will provide market information that plainly sets out our needs and simplify balancing services to create transparent markets.

This document is intended to give more information on our future system needs and to consult on how we can best facilitate the evolution of future balancing services markets. As developments occur, we will use our new Future of Balancing Services web page to provide additional information and updates as we progress with our thinking over the coming months.

We will also be working closely with our colleagues in the Distribution Networks to understand how best to facilitate a whole system approach to managing the network, ensuring parties at all levels of the system have the appropriate access and routes to market. As always, we are keen to understand your views and feedback either through the consultation questions within the document or more generally about this publication. Please contact us using the Future of Balancing Services email address: **box.futureofbalancingservices@nationalgrid.com**

Cathy McClay
Head of Commercial, Electricity

Contents

Executive summary

A flexible system that makes the best use of all available resources will enable the System Operator to meet its customers' needs in an economic and efficient way, particularly in a future smarter energy world. To do this, we intend to create balancing services that allow new and existing providers to participate.

You told us:

- balancing services are not accessible to all potential providers
- balancing services are complicated, they are unclear and not future-proof
- investors need to know our plans so they can make informed decisions of their own.

We are committed to responding to this feedback by creating balancing services that are simple, transparent and deliver value to the end consumer.

To make this happen we are:

- improving the information we share to make it easier for industry to see and meet our future system needs
- consulting on and simplifying our balancing services. We want to remove the barriers you have highlighted so the system makes better use of all resources.

System Needs and Product Strategy

This document *System Needs and Product Strategy* is the first step toward improving the information that we share. It has been published on our new Future of Balancing Services webpage. We will use this page to share the latest information about our needs and balancing services developments.
www2.nationalgrid.com/futureofbalancingservices/

In chapter one, we provide an overview of our **System Needs** over the next five years. We discuss how these needs are evolving (and increasing in certain timeframes). We also discuss the improvements required to balancing services to meet these needs.

On **Product Strategy**, we are asking for your engagement and ideas to simplify and evolve balancing services and the products that we use to address these system needs. This consultation should help us understand industry thinking about improvements that could be made to our various services and markets. Responses are invited using the survey on our webpage by 18 July 2017.

We will also be looking at the structure of our contracts, reviewing our testing and compliance requirements and trialling new procurement methods.

We will be engaging with industry over the next few months and publishing our post-consultation recommendations for a balancing services product strategy at the end of September 2017. At that time we will also have a detailed plan showing milestones for how our proposed strategy will be implemented.

Introduction

National Grid is the electricity System Operator for Great Britain. We are responsible for operating the GB high-voltage electricity transmission network in a safe, secure, reliable and cost-efficient manner.

Residual balancer
As the SO, we are the residual system balancer; this means we must ensure the balance between supply and demand is maintained continuously. We do this by refining the generation output and demand delivered by the wholesale market.

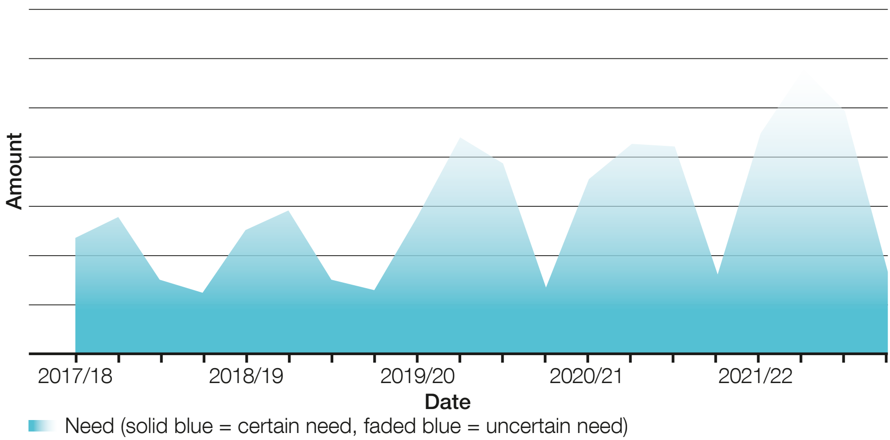
System needs
We must also ensure that the system is operated within a number of defined limits and that likely system events can be managed; in this document we describe these as ‘system needs’. We do this by accessing flexible generation close to real time in the Balancing Mechanism (BM) and by contracting for balancing services ahead of time where we are confident those needs will exist in real time.

Changing energy mix
Less synchronous generation on the transmission system and an increase in intermittent generation embedded within the distribution network has led to system needs becoming less predictable and more volatile. A reduction in generation available in the BM able to offer the flexibility that is needed to address the increasing volatility means we are taking more actions as the residual balancer for operability reasons.

Need for change
The approach of accessing flexibility in the BM and contracting for firm needs in balancing services has been fit for purpose in the past. It has delivered on our objectives of a safe, secure, reliable and cost-efficient system; however, the changing energy mix and the increasing requirement for cost-effective flexibility (either in the BM or otherwise) means that the current approach must be reviewed.

Figure 0.1 demonstrates the general trend for system needs over the next five years using illustrative data, with the increasing transparency aiming to show how our requirements become less certain at the extremes. In general, system needs are increasing, most notably at the extremes. The volatility of the extremes is also increasing. Currently we access the flexibility required to manage the extremes and volatility, near real time, in the BM (mandatory services and BM availability). More certain or ‘firm’ needs are procured further ahead of time in tendered balancing services markets. These firm needs remain relatively stable across the five-year timeframe. As the energy mix changes, the availability of flexibility in the BM is reducing or is becoming increasingly costly to access. Therefore routes to market must be created for all providers to offer flexibility across the SO’s range of requirements.

Figure 0.1
Illustration of balancing services trend



Our ambition is to work with industry to design and create a transparent, technology-neutral set of products that allow access to the flexibility that is increasingly required. ***System Needs and Product Strategy*** is the first deliverable of this ambition. It is divided into two distinct parts, the system needs and the product strategy consultation.

The System needs chapter provides:

- a summary of five key future system needs. These have been broadly written in the order they are required from real time.
  - Inertia and Rate of Change of Frequency (RoCoF)
  - Response
  - Reserve
  - Reactive Power/Voltage Support
  - Black Start
- a summary of how these needs are currently met and any potential improvements that could be made
- where appropriate, a forecast of how the needs change in the one to five year timeframe. It should be noted that any future improvements to balancing services will impact these forecasts.

Future requirement modelling

Throughout the System needs chapter we refer to data from our future requirement forecast model. This model uses a half hourly forecast of generation and demand using the methodology developed in *SOF 2016*. To display the requirements, we have chosen the **Consumer Power** scenario from the *FES 2016* as it most closely reflects the issues and trends that we currently experience.

To demonstrate the range of possible requirements, we present the data using the 50th percentile and 97.5th percentile values. The 50th percentile can be thought of as a medium or normal likelihood and the 97.5th percentile represents the high or extreme likelihood. A range is used due to the number of variables including demand, generation and weather.

Future product and service designs are subject to consultation. The forecasts included in this document are therefore modelled using today's products and service assumptions. We will update any forecasts as the products are developed.

Introduction

The Product strategy consultation chapter provides:

- details of the engagement programme and the steps we will take to review the way we procure balancing services
- a number of alternative approaches and options for the future
- consultation questions to gather industry feedback to begin the design process
- a timeline for the consultation, design and implementation of changes.

Future of balancing services

We will continue to use the Future of Balancing Services webpage to provide further updates and details as and when the product strategy develops. **www2.nationalgrid.com/futureofbalancingservices/**

If you would like to know more about our current balancing services please visit: **www2.nationalgrid.com/uk/services/balancing-services/**

If you would like to know more about our operability requirements from a technical perspective please visit: **www.nationalgrid.com/SOF**

Chapter one

System needs

System inertia and Rate of Change of Frequency

System inertia comes from the rotational energy stored in synchronous machines such as coal, nuclear, gas or hydro power plants.

Inertia determines how quickly frequency will change when there is an imbalance between generation and demand; the greater the inertia, the slower the change in frequency. As levels of wind, solar and interconnection continue to increase, system inertia is expected to decrease.

Inertia stabilises frequency and reduces the Rate of Change of Frequency (RoCoF). While faster acting frequency response helps to manage a higher RoCoF, some inertia is still required to hold frequency for long enough to allow even the fastest frequency response to be triggered[1].

System inertia and Rate of Change of Frequency summary

- Inertia stabilises frequency and reduces the Rate of Change of Frequency (RoCoF).
- System inertia is expected to decrease as the energy mix changes.
- RoCoF must be managed to avoid generation protection relays tripping.
- Reducing the largest credible loss will reduce maximum potential RoCoF following a loss. This is currently the most efficient solution.
- Increasing the levels of inertia on the system is less effective than reducing the largest credible loss, therefore we will not create a specific inertia product.
- Desensitising RoCoF relays will allow the system to operate at lower levels of inertia.
- Inertia is linked to managing frequency. Its value will be assessed as part of a new frequency response product to be designed and implemented by March 2018.

How do we manage inertia and RoCoF today and where do we see issues going forward?

The lower the level of inertia on the system, the higher the RoCoF will be in the event of a generation or demand loss. Some distributed generators have protection relays in place which will disconnect or 'trip' them from the system if a high RoCoF is detected[2]. In a worst case scenario, uncontrolled disconnection of large quantities of generation could lead to partial system shut down. This means at times of low inertia (which are coincident with times of low transmission demand) we must take more actions to keep the potential RoCoF below the trigger points of these relays.

[1] More details on the difference between inertia and faster frequency response can be found in chapter 3 of the *SOF 2016* www.nationalgrid.com/SOF

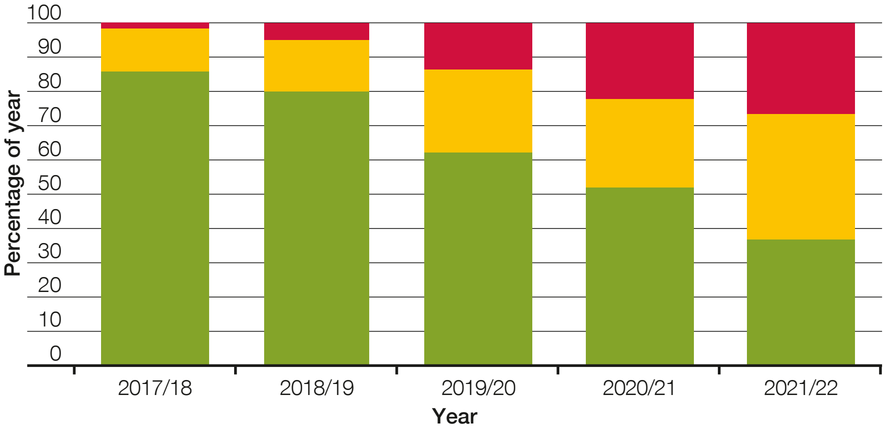
[2] RoCoF protection relays are in place to avoid damage to generator or network assets in case part of the distribution network is disconnected, however the settings are widely accepted to be too sensitive for the GB system.

Currently the most economic and efficient option to limit RoCoF is to limit the largest credible loss[3]. We do this by trading or by taking BM actions to reduce the level of the generation or demand that comprises the largest loss. This could be reducing the output of one generator (or multiple generators running at the same level) and increasing output elsewhere. Alternatively this could be reducing demand or export on an interconnector and reducing generation output to balance. Reducing the potential largest single loss on the system reduces the RoCoF on the system that would occur in the event of that loss. This therefore ensures that the system RoCoF is below the trigger points of the generation protection relays. In the future, as levels of wind, solar and interconnectors increase, system inertia will decrease further and reducing the largest loss to ensure RoCoF is below relay settings levels may not always be economic or possible.

Our inertia and RoCoF strategy

Figure 1.1 below shows the percentage of time that we might be required to take actions to reduce RoCoF. This is based on our half hourly requirements model using the **Consumer Power** scenario[4]. For the majority of time, RoCoF can be managed by reducing the largest single loss (shown in yellow); however, in the future, it may be increasingly necessary to take action to bring on additional synchronous generation to increase system inertia (in red) or to find an alternative solution.

Figure 1.1
*Five-year RoCoF trajectory (**Consumer Power**)*



[3] Chapter 5 of the Security and Quality of Supply Standards (NETS SQSS) defines the secured credible fault outages. http://www2.nationalgrid.com/uk/industry-information/electricity-codes/sqss/the-sqss/ The largest loss is the largest total demand or generation at risk from a single credible fault.

[4] For further details on requirement forecasts please refer to the Future requirement modelling section in the Introduction, page 5.

System needs

Taking specific action to increase system inertia is less economic than reducing the largest loss. Increasing the level of inertia on the system would reduce RoCoF, however, this option is less efficient than reducing the largest loss. Adding 3GW of synchronous generation to increase inertia will have approximately the same effect on RoCoF as reducing the largest loss by 100MW[5]. We therefore do not intend to manage RoCoF in this way and would not advocate a specific inertia market.

Desensitising RoCoF relays will allow operation of the system at lower levels of inertia. Distributed generators are undergoing a programme[6] to desensitise their RoCoF relays. This will enable system operation at lower inertia levels. This programme was initially expected to be implemented by August 2016, but has been delayed because more distributed generators are using these devices than was expected. A new target date for the completion of this work has not been set, but is likely to be several years away.

It may be possible to take the value of inertia into account in a new frequency response product. Since inertia is intrinsically linked to managing system frequency, it is appropriate to assess the value of inertia in the design of the frequency response product. Faster-acting frequency response helps to arrest a faster RoCoF, however, some inertia will still be required to hold frequency for long enough to allow even a very fast response to trigger. It may similarly be possible to value inertia in a future voltage market design. This concept will be explored as part of our product strategy work.

Synchronous compensators (including generators with a synchronous compensator mode) and similar devices can provide operational benefits such as inertia and voltage control without generating active power.
We are a partner in Project Phoenix which is a collaborative Network Innovation Competition funded project led by Scottish Power Energy Networks. The project will design, deploy and demonstrate the benefits of a new hybrid synchronous compensator. The commercial arrangements for synchronous compensator operation will also be explored further as part of our product strategy work.

[5] This is based on the contribution to system inertia of approximately six 500MW synchronous generators, each with an inertia constant of 6.26s. More information is available in section 3.5.3 of the *System Operability Framework* www.nationalgrid.com/SOF.

[6] Ofgem RoCoF relays modification proposal: https://www.ofgem.gov.uk/sites/default/files/docs/2014/07/gc0035_authority_decision_0.pdf

Frequency response

Part of our role is to maintain a stable system frequency. Frequency response is an automatic change in generation or demand to counteract changes in system frequency.

The amount of response needed is directly influenced by system inertia and the size of the largest generation or demand loss. The need is greatest when system inertia is low as frequency moves faster when inertia is lower.

- 'Dynamic' response is used to continuously follow and control minor deviations in frequency due to small imbalances in generation and demand.
- 'Static' response activates when a fixed frequency limit is breached. It is used, in conjunction with dynamic response, to contain a large frequency event such as generator or demand trips.

Frequency response summary

- Response is required to balance system frequency in real time.
- Response needs are increasing and the need is highest when the system inertia is low.
- We buy a firm volume of response through Firm Frequency Response (FFR) ahead of time. This volume is expected to be stable.
- The remaining, increasing and more volatile volume is accessed through Mandatory Frequency Response (MFR) in the BM closer to real time. This is currently economic and offers flexibility.
- Faster-acting response can reduce the overall volume of response needed.
- The flexibility offered by MFR is required for the volatility of the need, however providers are reducing.
- Changes to response products are required which provide a route to market for fast-acting response and the flexibility that we need closer to real time.
- This will be designed using industry consultation and implemented by the end of March 2018.

How do we manage frequency response today and where do we see issues going forward?
We need response that acts faster than the products that we use today and we need flexibility closer to real time.

- The need is highest when system inertia is low. With lower inertia on the system, the frequency moves more quickly. This means we need faster-acting response.
- The certainty of the need is also less because of variable factors such as transmission demands and output from wind and solar. This means we need a market structure that allows procurement and access to flexibility closer to real time as needs become more certain.

The alternative would be to procure greater volumes of the existing response products. While this would have the same effect in the short term, it is unlikely to be a sustainable or economic approach.

System needs

We procure response in two ways; the Firm Frequency Response (FFR) product and the Mandatory Frequency Response (MFR) market. FFR offers providers contracts from up to one month ahead. We use this to contract for volumes of response that are firm and where contracting is more economic than the alternative. The alternative is MFR, which is response accessed through flexible generation available in the BM closer to real time.

The FFR products and the MFR market do not provide a specific route to market for response faster than a ten-second (primary) initiation speed. In 2016, we ran a trial tender for sub-second Enhanced Frequency Response (EFR). Rather than a second tender, we believe faster response should be incorporated into the wider response products. Faster response, with controlled delivery, that can be sustained for longer is the most valuable.

The FFR products' structure and tendering process do not allow for the close to real time variability of the response needs. The MFR market does offer this, however the availability of the generation providing this flexibility in the BM is reducing.

Figures 1.2 and 1.3 show the response needs in a high and a medium requirements scenario[7]. The charts show the Primary response needs (i.e. required to manage low frequency) and the High frequency response needs across the next five years. We have displayed Primary response as a positive value on the chart axis, representing the increase in MW delivered and High frequency response as a negative value representing the decrease in MW delivered.

To demonstrate the effect sub-second response could have on the overall requirement, the upper line assumes 200 MW of sub-second response and the dotted line demonstrates the effect an additional 300 MW of sub-second response would have on the overall requirement (300 MW is used as an illustrative example and should not be interpreted as an indication of our future requirements for sub-second response). The blue line on Figures 1.2 and 1.3 shows the average amount that we currently contract for each month in FFR if economic. The average has been used to illustrate the FFR requirement as the actual amounts change monthly dependent on forecasts of transmission demand and inertia. More detailed information can be found in the FFR market report[8].

[7] For further details on requirement forecasts please refer to the Future requirement modelling section in the Introduction, page 5.

[8] FFR Market reports: http://www2.nationalgrid.com/UK/Services/Balancing-services/Frequency-response/Firm-Frequency-Response/Firm-Frequency-Response-Information/

Figure 1.2
*Primary and High response requirement (97.5th Percentile **Consumer Power**)*

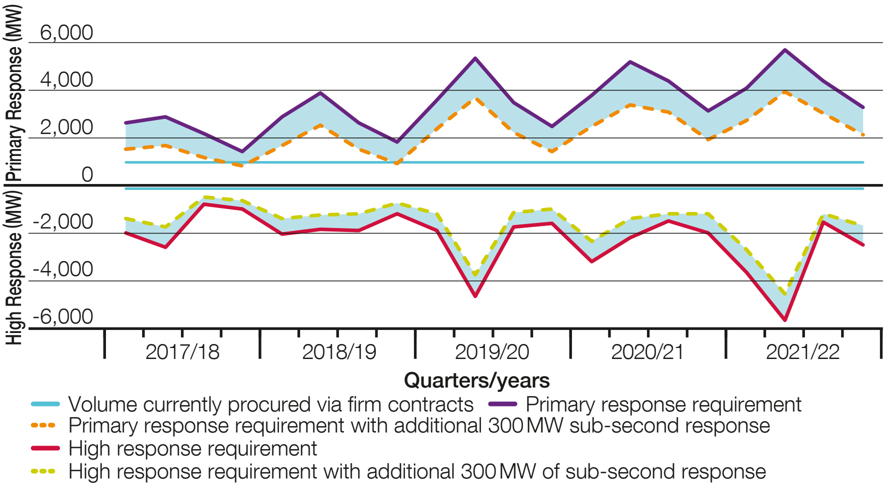
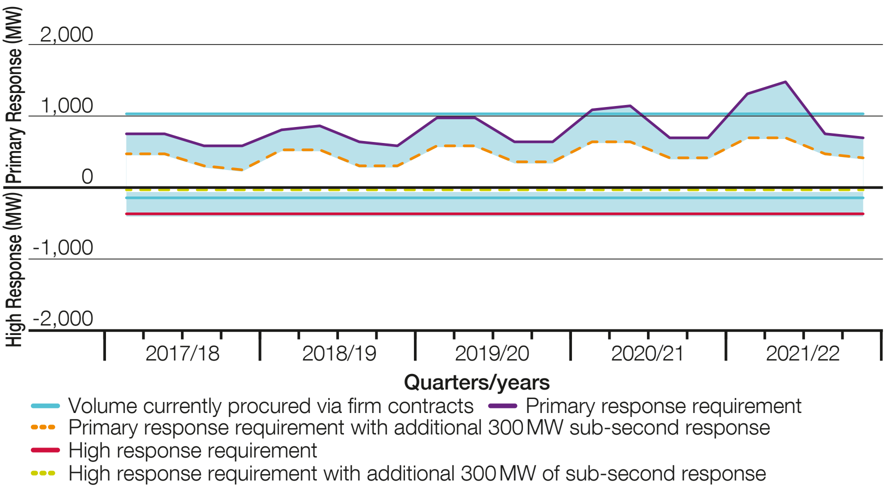


Figure 1.3
*Primary and High response requirement (50th Percentile **Consumer Power**)*



System needs

Our frequency response strategy

A response product is required to replace the existing FFR and EFR products. This should ensure access to the faster-acting response that is needed and increase transparency of how this is valued against existing response provision. The development of this will also allow us to explore closer to real time procurement of the flexibility that is needed. This could be achieved either through procurement closer to real time or procurement ahead of time with options for refinement closer to real time. The consultation questions within this document and further engagement with industry will be used to design and implement an improved frequency response product by March 2018[9].

In parallel to our product strategy work, we will also consider the outputs of the Enhanced Frequency Control Capability (EFCC) project[10], for which we successfully received Network Innovation Competition funding in 2014.

The project is exploring more advanced methods of triggering frequency response in sub-second timescales, coordinated via a wide area monitoring and control solution. This should allow a route to market for more providers.

The *Future Energy Scenarios 2016*[11] show that it is feasible that interconnector capacity could almost triple by 2022. Interconnectors are able to alter their input and output almost instantaneously. To prevent this from impacting system frequency, we currently impose ramping limitations through bilateral connection agreements. With unconstrained ramp rates, the amount of response needed could further increase. Our strategy for response must take account of this and we will continue to engage on this topic.

[9] The implementation of this new product will not change the response definitions for MFR.

[10] http://www.nationalgridconnecting.com/The_balance_of_power/

[11] The *Future Energy Scenarios 2016*: http://fes.nationalgrid.com

Reserve

Reserve is needed to ensure imbalances that arise from forecasting errors or unexpected losses on the system can be managed.

Reserve is manually instructed after automatic frequency response services have delivered. Reserve can be either upward (an increase in generation/decrease in demand) or downward (a decrease in generation/increase in demand). Reserve is also used to describe the actions that we take to ensure that sufficient upward and downward flexibility is available. We use a mix of balancing services products, the BM and trading to ensure that we have access to reserve in the necessary timescales.

Reserve summary

- Reserve is required to correct imbalances arising from forecast errors and the unexpected loss of generation or demand. It is manually instructed and slower acting than frequency response.
- The reserve required to correct for forecast errors and losses is relatively certain ahead of time. This is procured through tendered reserve products where economic. This firm need remains stable over the next five years.
- The actions that we take to ensure additional upward and downward flexibility are less certain and only become clear closer to real time. This variable need becomes more volatile and increases as response requirements increase.
- Access to flexible plant that provides reserve in the BM is limited at times of low transmission demand.
- New reserve products must be developed that ensure:
  - sufficient flexibility is available close to real time
  - market access for both BM and non BM providers
  - compatibility with pan-European reserve services.
- We will consult with the industry to develop and implement this new product. The ambition is to complete this by 2018/19 depending on industry feedback.

How do we manage reserve today and where do we see issues going forward?

Firm volumes which are required for managing demand forecasting errors and large losses are procured via regular tenders ahead of time (e.g. Short Term Operating Reserve (STOR) and Demand Turn-Up (DTU)). In addition, variable volumes are required for upward and downward flexibility. These are satisfied closer to real time by part-loaded plant operating in the energy market, instructions in the BM, or trading. There is now less certainty as to how these variable requirements will be satisfied closer to real time as the levels of wind and solar generation have increased.

System needs

An increasing proportion of the potential reserve providers that are available in the BM are needed to meet frequency response requirements. Providers of frequency response cannot use the same capacity for reserve while continuing to provide response. The number of potential reserve providers in the BM is therefore reducing. At times of low transmission demands there are fewer providers available in the BM.

Figure 1.4 shows the firm needs for upwards and downward reserve over the next five years based on the 50th percentile[12] from the requirements forecast. Figure 1.5 shows the range of variable volumes that we require using the 97.5th and the 50th percentile of the requirements forecast. The 97.5th percentile requirement is large but infrequent. We would therefore not procure this as a firm need ahead of time. However, we must ensure we have capability to manage the more variable extremes.

Downward reserve
Our firm downward reserve need in this scenario is stable between 1 and 2 GW (Figure 1.4). Our variable need for this year is between 3 and 5 GW, however we expect this to increase over the next five years (Figure 1.5). Currently both our firm and variable downward requirements are mostly accessed through the BM or trading, however this availability is reducing, particularly at times of low transmission demand. To increase the options available to us, we have therefore recently tendered for demand turn-up and also issued an expressions of interest for other downward reserve options such as the ability to reduce minimum generation output[13].

Upward reserve
The firm upward reserve requirement is stable and remains between 2 and 3 GW (Figure 1.4). The firm requirement we will procure in STOR will remain at 2.3 GW if economic (shown by orange line in Figure 1.4) and any real-time deficit can be accessed in the BM. This however offers limited transparency and will be decreasingly effective as potential reserve providers are less available in the BM. The variable upward reserve required for flexibility increase over the next five years as response requirements increase.

[12] For further details on requirement forecasts please refer to the Future requirement modelling section in the Introduction, page 5.

[13] http://www2.nationalgrid.com/uk/services/balancing-services/Reserve-services/Footroom/Footroom-servies/

Figure 1.4
*Upward and downward firm reserve requirement (50th Percentile **Consumer Power**)*

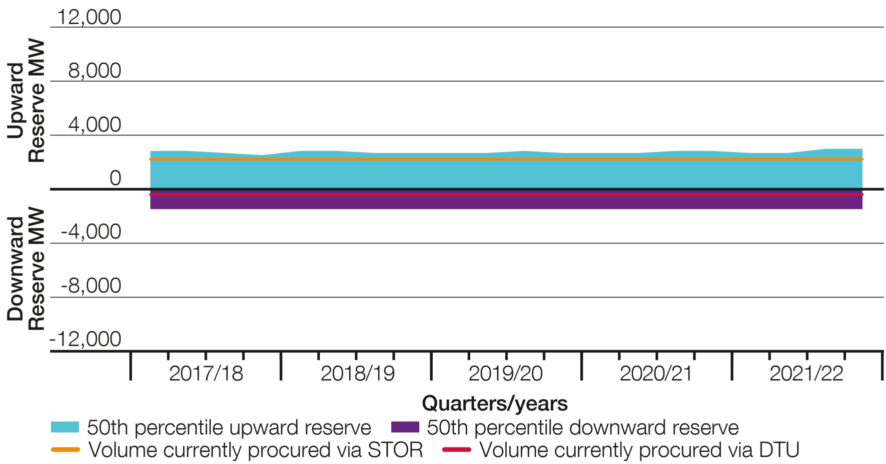
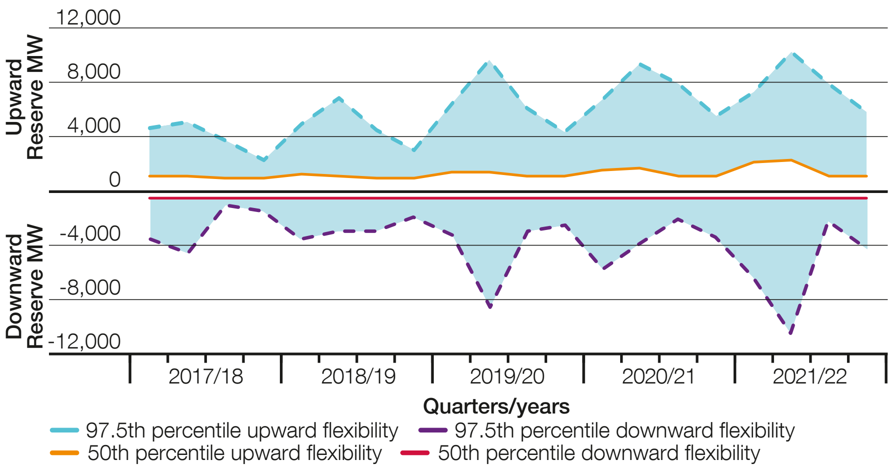


Figure 1.5
*Range of upward and downward flexibility required (**Consumer Power**)*



System needs

Our reserve strategy

Currently there are a number of different balancing services products for reserve that have overlapping timescales of delivery and differing technical requirements and characteristics. These multiple products inhibit transparency of the total market opportunity. We will be rationalising and simplifying these services through our product strategy work, considering both upward and downward reserve services. Our ambition is to consult with the industry to develop and implement a new reserve product in 2018/19.

In improving the products, we must take account of European developments in this area. Project TERRE will introduce the first standardised pan-European reserve service, RR (Replacement Reserve), going live in 2019. Future standardised reserve services must also be factored into our market design, such as mFRR (manual Frequency Restoration Reserve), due to go live in 2021.

From Quarter3 2018, the trading arrangements across interconnectors to Europe will change. Currently, the interconnectors are a cost-effective and reliable tool for managing a number of system needs including reserve. New cross-border trading arrangements will make trading available up to one hour ahead, as opposed to three hours ahead today. This will increase uncertainty in our generation and demand because interconnector flows could change closer to real time. We are investigating the impact of this and it must also be considered in any new product design.

Reactive power

Reactive power (measured in Mvar) is used to control voltage. Generation, demand and network equipment (such as transformers, overhead lines and cables) can either generate or absorb reactive power. These contributions need to be kept in balance to keep the voltage at the right level. Voltage is a local property of the system so requirements vary from one region to another.

Reactive power summary

- The generation or absorption of reactive power is used to control voltage which must be maintained within prescribed limits.
- More reactive power absorption is needed to prevent high voltages at time of low transmission demands and there are specific locational sensitivities.
- The need is addressed by using network-based assets (reactors and capacitors) and by accessing the mandatory reactive market in the BM.
- The existing mandatory reactive market does not properly value the reactive power capability.
- The existing mandatory reactive market is not accessible to Distributed Energy Resources.
- A new reactive market will be designed and implemented by the end of 2018/19. We will use industry engagement and the findings of the Power Potential project.

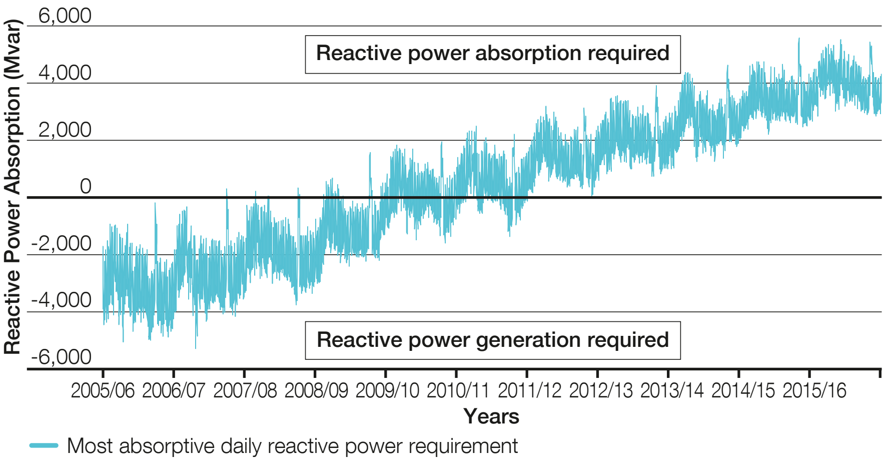
How do we manage reactive power today and where do we see issues going forward?

When transmission demand is low, electricity networks tend to generate reactive power. This means that the voltage will increase unless additional reactive power absorption is available. When transmission demand is high, networks will tend to absorb reactive power. In this case, voltage decreases unless additional reactive power generation is made available.

Figure 1.6 shows that the need has moved from the generation of reactive power to the absorption of reactive power. This trend is driven by low transmission demands and increased reactive power contribution from distribution networks. We expect the need for absorption to continue to grow.

System needs

Figure 1.6
Reactive power requirement



We currently manage reactive power using network assets such as reactors and capacitors, and mandatory provision of reactive power from generators in the BM.

Most of our voltage control challenges occur in the summer when demand on the transmission system is low and fewer flexible generators are running. The locational nature of reactive power means that we may have to instruct synchronous generation to start up where we need extra reactive power absorption and therefore must instruct some generation to stop generating to keep the system balanced.

At times when additional reactive support is required, we issue instructions for active power to access the mandatory reactive range provided by BM participants. Mandatory reactive power is paid at a value of £2.386/Mvarh (summer 2016) £2.565/Mvarh (winter 2016/17). The mandatory price calculation is based on a legacy methodology that reflected the cost at the time to synchronous generation of providing reactive power. This price does not represent the full cost of providing or procuring mandatory reactive power. The cost of instructing generation to run so that we can access the mandatory reactive service needs to be included to give a better indication of the value.

Our reactive power strategy

We must reassess the commercial valuation of reactive power and consider locational sensitivities. This must be supported by clearer signals of need and appropriate routes to market for potential providers. We also need to access reactive power from generation when at low or no active power output.

Presently, there are a number of technical barriers to Distributed Energy Resources being able to provide reactive power to the transmission system. The Power Potential project (formerly known as TDI 2.0[14]) seeks to investigate how to access reactive power from distributed providers. The project will trial enhanced coordination with UK Power Networks to ensure reactive power can be delivered to the transmission system and correctly valued.

Synchronous compensators, as described in the inertia chapter, could offer multiple operational benefits without generating active power.[15] Project Phoenix will explore synchronous compensators as an approach to meeting requirements for both inertia and voltage control.

We must create a market that values reactive power in a transparent manner and aim to do this by the end of 2018/19. This design will begin following consultation and will use the results of Power Potential and Project Pheonix.

[14] More information on Power Potential (formerly TDI 2.0) is available on Ofgem's website: https://www.ofgem.gov.uk/network-regulation-riio-model/network-innovation/electricity-network-innovation-competition/national-grid-electricity-transmission

[15] More information on Project Phoenix is available on Ofgem's website: https://www.ofgem.gov.uk/network-regulation-riio-model/network-innovation/electricity-network-innovation-competition/scottish-power-transmission-limited

System needs

Black start

Black start is required to enable the restoration of the electricity network if the transmission system or a large section of the system shuts down. In this very unlikely event, it is important that we are able to restore power in a timely manner.

Black start summary

- Black start is the service used to restore the system in the unlikely event of a partial or total shut down.
- The total number of black start services required is expected to remain the same.
- The availability of existing providers is expected to reduce as thermal generation moves away from base load output.
- There are opportunities for new providers to enter contracts to deliver black start services from 2018.
- There are opportunities for new alternative technology providers, however they must meet a set of technical requirements.
- We are reviewing our black start strategy to better suit future generation backgrounds and consider alternative approaches to system restoration.
- Our longer-term strategy is to investigate Distributed Energy Resources, aid the introduction of a formal restoration standard and procure services through tenders where appropriate.

How do we manage black start today and where do we see issues going forward?
To restore power, we need generation capable of starting up without external power supplies, energising the transmission system and supporting the reconnection of demand. We ensure there are enough generators which have this capability by entering into black start contracts.

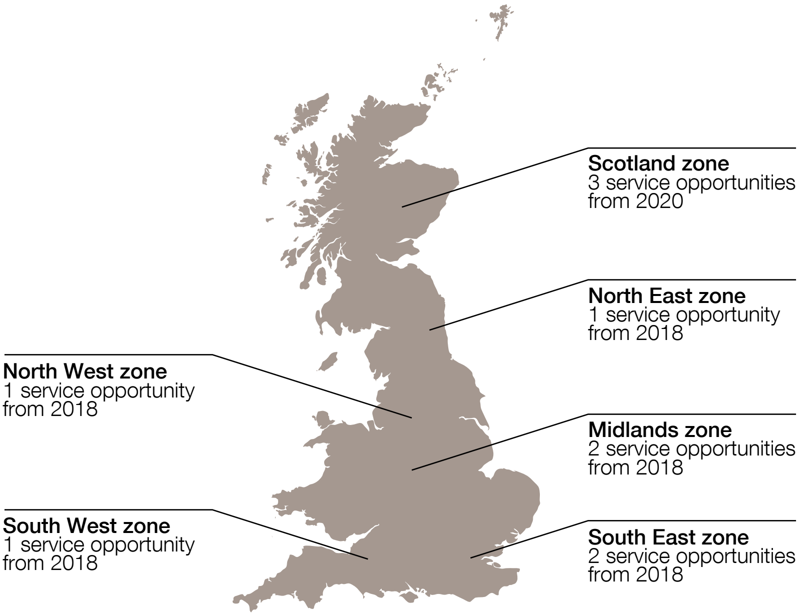
The requirement for black start services is not increasing. However, the availability of some of our existing providers is expected to reduce as thermal generation moves away from base load output. This change means that opportunities are becoming available for new providers on a more regular basis. Contracts are assessed both on their technical capability[16], contribution to restoration, locational requirements and economics.

[16] http://www2.nationalgrid.com/uk/services/balancing-services/system-security/black-start/

Our current strategy is to divide the system into six zones and then procure up to three services in each zone. While not all services would be required in the event of a system restoration, a higher number of services allows for more restoration options and gives greater resilience to failures or unavailability at any given time. Not all power stations will be capable of meeting the technical requirements for black start and we must also strike a balance between the number of providers and the cost of procurement.

Figure 1.7 summarises the zones and where there are opportunities for new black start provision in future years. These dates are based on the length of existing contracts; once a contract expires, those services would be renegotiated or replaced by new providers. Zones do not have exact boundaries and can be flexed around the contracted services.

Figure 1.7
Map of black start service opportunities



This requirement is based on our current restoration strategy. This restoration strategy is under review and alternative restoration approaches taking into account the changing market conditions (e.g. significant levels of Distributed Energy Resources) are being considered for the future.

System needs

Our black start strategy

Our strategy over the next one to two years is to investigate how alternative transmission-connected generation can be used to support the restoration strategy. The following opportunities are under review.

- VSC (Voltage Source Converter) interconnectors have the potential to provide services.
- Intermittent generation is yet to be proven but may be able to play a role in restoration.
- Upgrades to thermal stations leading to a station being able to maintain black start capability for longer periods without having to run on a regular basis.
- Generation that is able to automatically island itself from the transmission system in the event of a disturbance (and remain operational). This small power island could then be used to support the restoration of the wider network.
- Small generation working in partnership with large generation rather than building new auxiliary generators.

Our longer-term strategy is to consider restoration standards, approaches and procurement methods.

- An initial step in this process is to publish the current black start restoration strategy and procurement methodology in summer 2017 which will improve the transparency of these aspects of the service.
- We will aid the development of a clear restoration standard or timeframe for restoration and adapt our restoration strategy to ensure the agreed standard is met.
- Investigation of alternative restoration approaches for example restoring the network via an initial spine or restoring demand more locally using distributed generation. Both approaches are very different to what we do today and technical considerations such as additional reactive power requirements, communication, control, network capability, role of a DNO and restoration modelling need to be considered in detail.
- Subject to sufficient market liquidity, which could be improved by our work to investigate alternative technologies and restoration approaches, a tender approach could be developed to procure Black Start.

Table 1.1
Summary of the system needs discussed in this document

System need	What is the need?	Why is the need changing?	Where is the need?	How will we address the need?	When will we address the need?
System inertia/ Rate of Change of Frequency (RoCoF)	■ Inertia is required to ensure the Rate of Change of Frequency is manageable. ■ The number of occasions that the SO must act to manage inertia or RoCoF are increasing.	■ Less generation on the system providing inertia means that frequency changes happen more quickly.	■ General system need; while there is variation in the RoCoF across the system we currently need to manage system-wide and do not currently resolve on a locational basis.	■ Programme to desensitise RoCoF relays. ■ Reduce largest loss below RoCoF relay trigger points when required.	■ Ambition is to improve response products by March 2018. ■ RoCoF relay programme began in 2016 for >5MW generation. Second phase currently being designed to address smaller generation.
Frequency response	■ Response needs become more volatile with greater extremes. ■ Increasing need for fast-acting sources of frequency response. ■ Tendered firm volumes remain fairly stable.	■ Less generation on the system providing inertia means that frequency changes happen more quickly.	■ General system need; no specific locational sensitivities.	■ New response product design which will include inertia and sub-second response. ■ Until launch, continue to contract for firm needs ahead of time in tendered markets and access close to real-time flexibility in BM through mandatory services.	■ Response product to be designed and launched by March 2018.
Reserve	■ Reserve needs become more volatile with greater extremes. ■ Increasing need for downward reserve when transmission demand is low. ■ Increasing need for close to real-time flexibility. ■ Tendered firm volumes remain stable.	■ Reserve needs increase due to uncertainty in weather-based generation and uncertainty of small-scale generation.	■ General system need; no specific locational sensitivities.	■ Standardise current reserve products to increase transparency of value. ■ New reserve product design to allow closer to real-time procurement of flexibility. ■ Flexibility accessed in BM through mandatory services.	■ Standardisation of current reserve products to be completed summer 2017. ■ New reserve product to be designed and launched in 18/19.

System needs

Table 1.1 continued
Summary of the system needs discussed in this document

System need	What is the need?	Why is the need changing?	Where is the need?	How will we address the need?	When will we address the need?
Voltage control	■ More reactive power absorption is needed to prevent high voltages when the network is lightly loaded. ■ The BM mandatory reactive market does not transparently signal the requirement as it relies on dispatching MW to access reactive support.	■ Less synchronised generation available to provide reactive power support. ■ Lower transmission demand means the network is lightly loaded which in turn generates reactive power.	■ Reactive power is a locational need. The current market structure does not support locational signals.	■ Design a reactive market which values the reactive power support required and provides location signals. ■ The Power Potential project will investigate routes to reactive market for Distributed Energy Resources.	■ Power Potential and market design to be completed 18/19.
Black Start	■ Requirement for new providers and better understanding of how alternative technologies can contribute to restoration. ■ Total requirement up to 18 services across 6 geographic zones.	■ Less synchronised generation available to provide Black Start. ■ Current restoration strategy suited to large synchronous generation.	■ Future contractual opportunities in all 6 geographic zones.	■ Publish more information with regard to our current restoration strategy. ■ Design a more transparent approach to black start procurement which enables greater competition.	■ Restoration strategy to be published summer 2017. ■ Contract opportunities available from April 2018.

If you would like to know more about our current balancing services please visit: **www2.nationalgrid.com/uk/services/balancing-services/**

If you would like to know more about our operability requirements from a technical perspective please visit: **www.nationalgrid.com/SOF**

Chapter two

Product strategy consultation

In order to address the limitations with the existing balancing services and better meet the challenges of the changing technology mix, we will simplify our product range.

The goal is to provide clear and consistent signals (aligned with the system needs) to support investment decisions, lower barriers to entry for new technologies and new business models, and deliver the most economic outcome for consumers. In line with this goal, we want to ensure that parties can optimise wherever possible the use of their assets by offering multiple services to multiple market participants including DNOs.

This work will initially be progressed through simplification of existing products and markets, but the intent is to trial more fundamental shifts in procurement such as day ahead markets and cleared price auctions to explore new approaches. We are also working with DNOs to understand their current and future service needs to ensure that any developments do not create barriers to future whole system approaches.

Finally, the intention is to future-proof our balancing services in order to provide stable and investable markets, which include and complement the forthcoming pan-European balancing products. We will be publishing our initial thoughts on whole system optimisation and the creation of new markets for constraint management in a separate paper in July. We welcome feedback on all aspects of our proposed approach. We have listed a number of consultation questions at the end of this section. Please respond to this consultation by 18 July 2017 using the survey on our **webpage**.

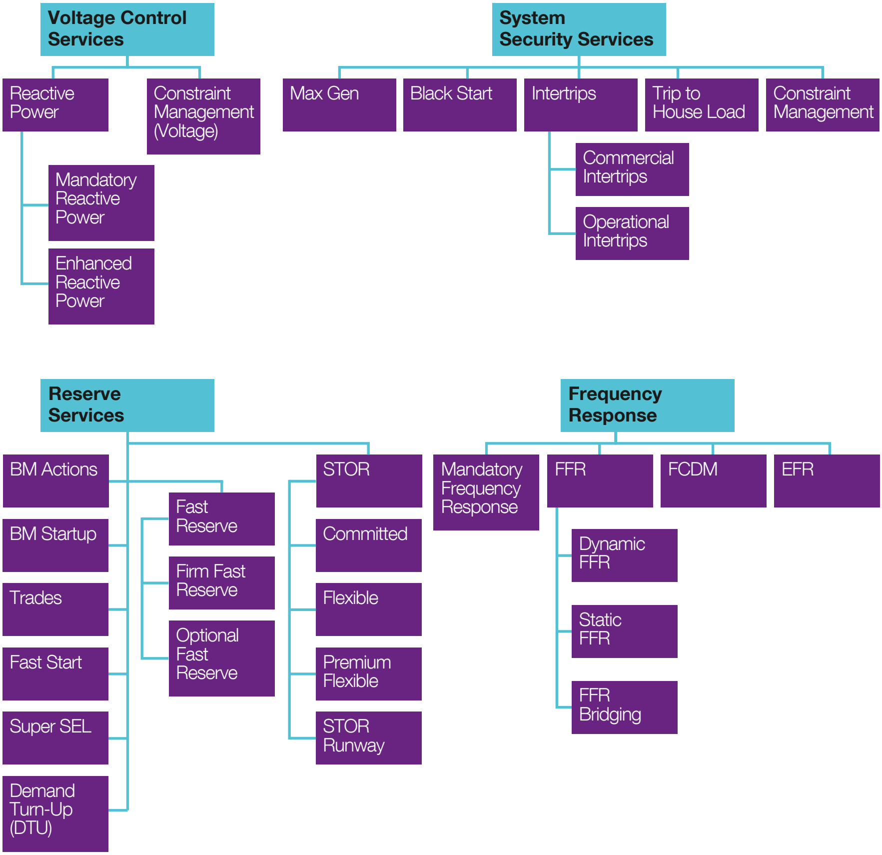
State of play of existing markets

In September 2016, we carried out a survey to understand the issues with the current balancing services markets, and identify the characteristics that parties would ideally want from these markets. We received over one hundred responses from individuals and providers, and from those responses a number of themes emerged.

Too many products

The existing service suite and the products within them have been built up over many years as our needs have gradually shifted. There are, however, now more than 20 different products that providers can choose from, each with different technical requirements and routes to market, as summarised in Figure 2.1.

Figure 2.1
Existing product suite

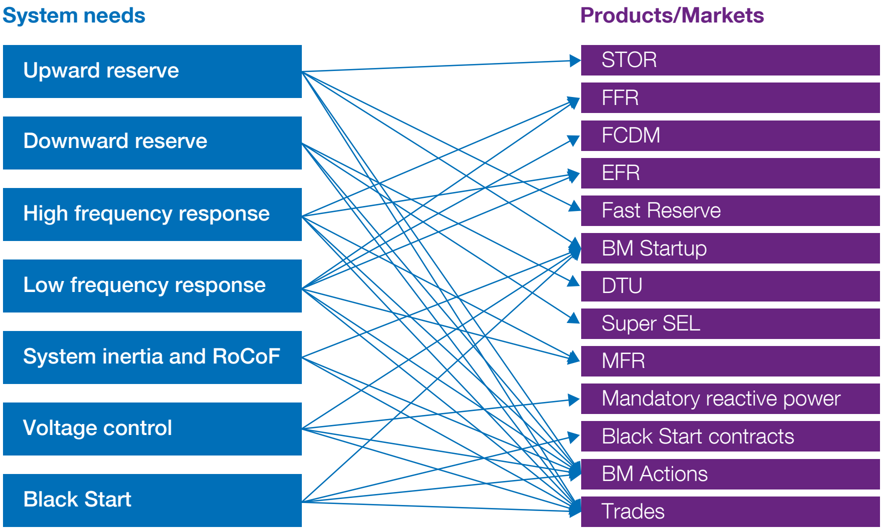


How we buy each product is different, but the purpose of each one is to ensure that we have the tools available to maintain the quality and security of the electricity supply at the lowest cost to consumers. This complexity creates a barrier to entry. This affects existing providers as well as new providers, new technologies and business models which may not fit into current product structures.

Product strategy consultation

Unclear requirements and interactions
The system issue that a particular market or product is attempting to address is often not clear to participants. In many cases the requirement is being driven by several system issues which interact, and this interaction is not communicated to the market in advance of assessment. Furthermore, requirements can change from tender to tender as a result of variations in some of the underlying system issues with little or no explanation to tendering parties. These issues together result in confusion over why certain tenders have been accepted and others have not, and also uncertainty over the stability and long-term sustainability of our markets. Figure 2.2 illustrates some of the overlaps and interactions between our needs and current suite of products.

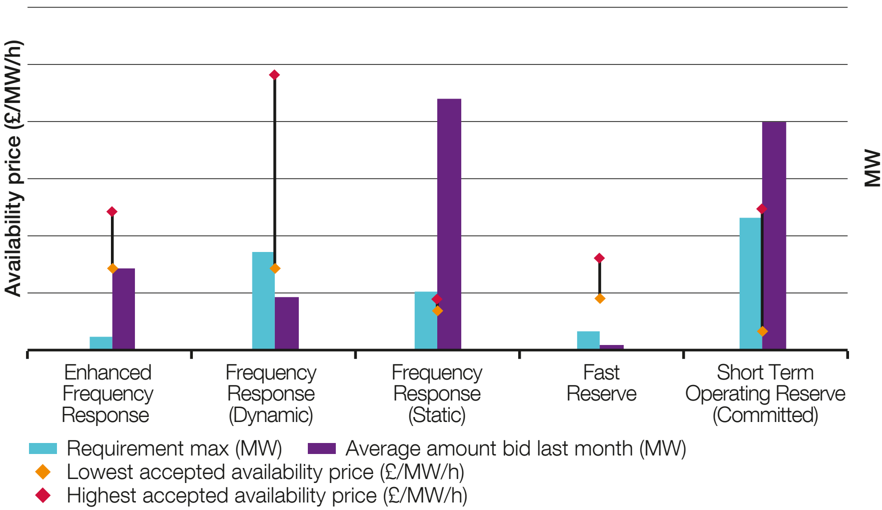
Figure 2.2
Mapping of current markets and products to system needs



Unclear assessment criteria
Even within tendered markets such as FFR and STOR, there is little consistency in terms of offering standard products that are easily comparable by market participants post-assessment. In FFR, factors such as the length of contract period or how quickly an asset ramps up in response to a frequency deviation are left up to providers to specify, with no guidance as to how we attribute value to these parameters during assessment. Equally in STOR, the trade-off between utilisation price and availability price and our assumptions behind procurement decisions is not transparent. This creates uncertainty and inhibits competition in these markets.

Overlapping markets
When considering individual products, it becomes apparent that there is considerable overlap in terms of what each product is trying to achieve. A further consideration is the way that each one of these overlapping products is procured. Some are tendered, some are bilateral, but all are assessed and contracted for by separate processes. Looking at a snapshot of the products delivering the services in Figure 2.3, it can be seen that the products with a significant oversubscription are those with the lowest accepted availability price, whereas undersubscribed products have a higher accepted availability price.

Figure 2.3
Oversubscribed and undersubscribed markets



If the products are very similar in terms of technical requirement and capability, yet they are being procured and valued in isolation, then the markets may not be delivering the optimum economic outcome for the consumer.

Product strategy consultation

Simplify the existing products

We will address the issues outlined above through a three-stage programme of rationalisation, standardisation and improvement with significant engagement with providers.

Stage 1 – Rationalisation
A number of products are no longer required in their current form, or have been superseded by later products. We are therefore proposing a review to reduce the suite of products that we procure. Existing contracts for these products will still be honoured, but the potential to move to market-based alternatives will be offered where possible. This does not necessarily mean that the requirement behind the product has reduced, just that there is or will be an alternative route to market for those providing the product.

Stage 2 – Standardisation
Our existing markets (e.g. FFR, Fast Reserve and STOR) include a number of parameters which parties can vary when submitting tenders. In addition to the information on interactions and requirements provided in this document, we will also be looking to provide more definition around these tendered parameters through standardising the products within each service market. Approaches to this include fixing parameters such as:

- daily availability windows, e.g. 24-hour, 24-hour triad avoidance, overnight, evening peak
- contract terms, e.g. 1 month, 6 months, 1 year, 2 years
- frequency response droop curve, e.g. minimum MW delivery at 0.2, 0.5 and 0.8Hz deviations
- speed of delivery of reserve energy, e.g. 2 minutes, 5 minutes, 10 minutes, 20 minutes.

We will also be reviewing our contract terms to ensure that they are fit for all technology types that could provide the service. We will continue to work with industry to understand the optimum way to standardise the existing markets through the change proposal governance process.

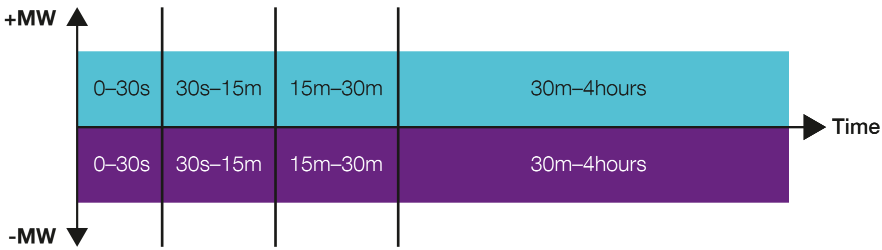
Stage 3 – Improvement: single product versus standardised products
We want to ensure that the products that we buy are fit for purpose now and in the future. We will therefore work with the industry to improve and develop our product suite beyond just standardising the existing market products. We will improve the products we buy to better meet both changes in the technical abilities of the assets providing the services, and changes in the commercial arrangements supporting the investment and operation of those assets. The proposed approach to this will be set out in our forthcoming product strategy report, which will be based on industry views provided through this consultation on the options outlined below.

Figure 2.4
Spectrum of standardisation and diversity

In any market, there is a spectrum between how standardised the products being bought and sold are (Figure 2.4). For example, a stall selling fruit will have different product types ('apples', 'bananas', etc.), whereas a car showroom has a single product ('cars') but will also include diverse variables such as different ranges, model types, optional extras, financing and servicing packages. At this stage we are not advocating any one path, but rather setting out possible approaches and seeking feedback from industry as to which would best address the issues raised through the survey and provider groups.

Standardisation
Standardisation would involve reviewing the existing markets and changing the products within them to ensure that their parameters best fit our operational needs and the abilities of existing and new technologies. As with 'single product', this approach would also involve needing to accurately define the value functions of the various parameters, as this information would be crucial in defining what the standard products were. Figure 2.5 is an example covering response and reserve services. One potential effect of this approach would be to facilitate secondary trading of balancing products, and the importance of this is something we value feedback on.

Figure 2.5
Example of standardised products



Product strategy consultation

Where assets could not provide the full product there could be a penalty structure applied to the settlement, which could be based on the value function of the variable not met. For example, an asset providing 30s–15minute energy which was limited to responding in 35s would have a penalty based on the difference in value between 30s and 35s energy delivery.

Single product

Taking a single product route would involve combining the products within each market (e.g. for frequency response combining enhanced, primary, secondary, high, dynamic and static frequency response), thereby moving from multiple product with single tendered variables to single products with multiple tendered variables. The key to combining and simplifying those products would be to identify their individual technical and commercial parameters, and understand the relationships between them. In summary we would be moving from a number of precisely defined products to a smaller number of products which have a number of parameters.

Products could be grouped based on similar technical and operational characteristics; this would be based on a qualitative assessment of the technical requirements, the timescales involved, and the operational need that they are addressing. The following groupings were identified from the existing suite of products as having the potential to form deeper markets (Figure 2.6).

Figure 2.6
Possible product groupings under a diversification approach

Frequency Response Products
Enhanced Frequency Response (EFR)
Firm Frequency Response (dynamic)
Firm Frequency Response (static)
Firm Frequency Response (bridging)
Frequency Control by Demand Management
Mandatory Frequency Response

Voltage Control Products
Mandatory Reactive Power
Enhance Reactive Power
Constraint Management (Voltage)

Reserve Products
Fast Reserve
Demand Turn-Up
Short Term Operating Reserve
Short Term Operating Reserve Runway
Super SEL
Fast Start
BM Startup
BM Actions
Trades

System Security Products
Black Start
Max Gen
Intertrips
Trip to House Load
Constraint Management

Within each group, the value of the parameters of each product would need to be determined. These value functions, or exchange rates, would need defining along with the interactions between them and any caps/collars on amount required. These value functions would be built into an optimisation algorithm to assess providers' submissions from the market. This algorithm would deliver the least cost solution based on all the different submissions and associated parameters.

The table below shows an example of how providers may bid into a Frequency Response market:

Table 2.1
Illustrative single product FFR tender submissions (other variables could be included)

Parameter	Provider 1	Provider 2	Provider 3
Speed of response (s)	3	1	10
MW delivered (MW)	120	70	300
Duration (minutes)	12	2	30
Unit price (£/MW/h)	17	10	6
Availability (hours)	24	12	20

One key success factor would be that the value functions are clear and transparent to participants, and that the assessment process is clearly understood.

Standardisation versus single product

There needs to be continuous dialogue with the industry to design new products that are fit for purpose, meet the needs of providers and reward flexibility. We will also ensure that there is enough time for parties to become familiar with the new structure ahead of implementation.

Existing contracts for affected services will not be cancelled, and successful tenders as well as bilateral contracts will continue as agreed. Our intention throughout this process of change is to minimise disruption to existing providers as far as possible, and to test improvements made to the products before introducing further change.

Stage 3 – Improvement: long-term versus short-term contracts

A key design question in developing the future product strategy relates to industry's preference for short-term markets or longer-term contracts to drive investor confidence in developing new flexible assets.

Stakeholders have told us that short-term markets (e.g. day ahead) can provide confidence to investors as every day provides a new opportunity for revenues. This could also unlock more demand side capacity because office, consumption and manufacturing processes are more certain nearer to real time. It may also allow us to be more certain about our requirement, and therefore increase the volume that we buy through the market. On the other hand, some parties have outlined the need for longer-term contracts to provide the revenue streams to support investment. We believe that there may be merit in providing a long-term route to market in the current climate to instil confidence in balancing services' revenue streams, particularly if and while short-term markets are developing. We continue to welcome industry views on this design decision.

Product strategy consultation

Future vision and consultation

New procurement approaches

There is a question over whether the existing pay-as-bid tenders are the appropriate approach for procuring balancing services. Depending on the approach taken to improving the products, standardisation or a smaller number of products with more variables, there are different procurement methods which could be trialled. Pay-as-bid tenders are useful when there is a market with a small number of participants and where there are highly standardised products, however a pay-as-clear auction approach may incentivise bidding at marginal price and increase transparency of the pricing signal in a market with standard products. There are also auction designs which are well-suited to optimising across multiple tendered variables which could be trialled in the frequency response market towards the end of 2018. We would also like to test markets that are closer to real time (e.g. day ahead or week ahead) in 2018.

Wider markets

The current set up of the balancing mechanism (BM) does not currently provide a viable route to market for non-traditional business models such as demand aggregation, distributed generation and DSR providers, due to the high cost of participation and compliance. We fully support introducing wider access to the BM and will be working with the industry over the coming months to determine how this could be implemented, taking into account all of the initiatives already underway (e.g. Project TERRE solution).

We are also working to understand the implications of the various Distribution System Operator models that are currently being developed, and increasing coordination across the networks. We will be publishing our initial thoughts in this space in July.

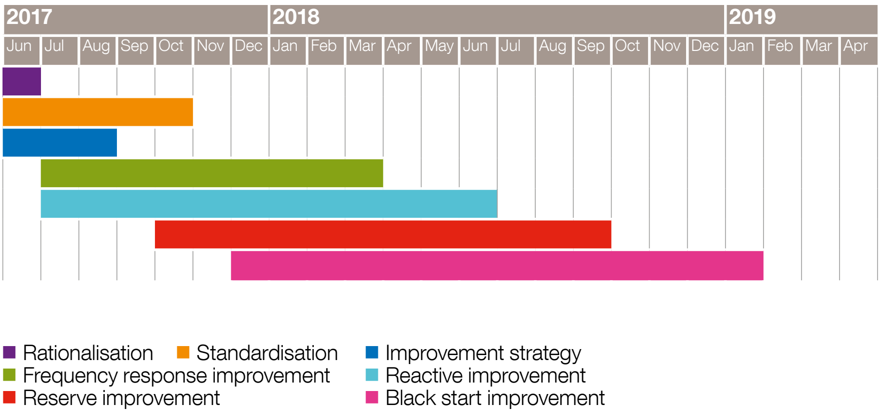
Other market design changes which we believe should be explored include regional market signals and any additional changes to the wholesale market identified as part of our ongoing engagement with market participants.

Timetable

The exact nature of the developments undertaken will depend on the industry feedback that we receive through this consultation and subsequent engagement.

We have set out a high level aspirational timetable for the work areas below. This will be complemented by continuing our programme of stakeholder engagement.

Figure 2.7
Timeline for key work areas



Product strategy consultation

Consultation questions

We welcome views on all aspects of our approach to simplifying balancing services markets to address the issues that have been raised by industry. We have listed some specific questions below to provide structure, but we would be interested to hear any feedback on the issues and pathways set out in this section. Please respond to this consultation by 18 July 2017 using the survey on our **webpage**.

Q1.
Do you agree with the summary of the issues identified around balancing services markets? If not, what additional concerns do you have?

Q2.
Do you agree with our approach to resolving the issues identified through simplification of the product suite? If not, what alternative approach should be taken?

Q3.
What are your views on the possible approaches to standardisation of the existing markets?

Q4.
What effect will fixing product parameters have on transparency and competition in the markets?

Q5.
What are the pros and cons of the two approaches to service improvement: single product and standardisation?

Q6.
Where do you see the optimum balance being between single product and standardisation?

Q7.
What are your views on the benefits and disadvantages of secondary trading in balancing services, and how do single product and standardisation affect secondary trading?

Q8.
How would the two approaches, single product or standardisation, affect the ability of providers to stack multiple services, and how important is this aspect when also considering short- and long-term contracts?

Q9.
What are the pros and cons of short- and long-term markets particularly in respect of existing and new-build assets?

Q10.
What do you consider to be the most appropriate route to support the delivery of new flexible capacity or capability?

Q11.
What are your views on the possibility of trialling different procurement approaches such as cleared price auctions and day-ahead markets?

Q12.
What other changes need to be made to other markets, such as the Balancing Mechanism, wholesale market and capacity market?

Q13.
What considerations should be made during this work to ensure that any future DSO developments (i.e. the procurement of balancing services by or from distribution networks) are coordinated?

Disclaimer

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Access our current *System Needs and Product Strategy* document and data at: www2.nationalgrid.com/futureofbalancingservices

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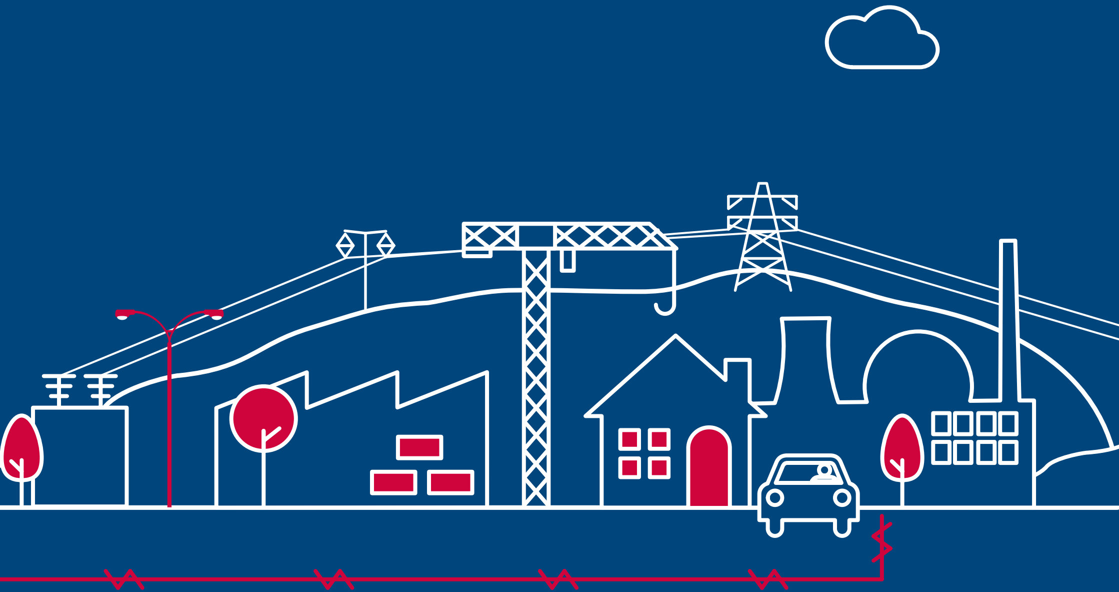

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