nationalgridESO

Security & Quality of Supply Standards

Frequency Risk and Control Report

Report – April 2021 (v1)

1. Foreword

Following the power disruption on 09 August 2019, the ESO has worked with industry to implement changes to the codes and frameworks which govern the management of frequency risks on the GB system. The outcome of these changes is the following *Report* produced in line with the *Methodology* which was consulted on in January 2021.

The ESO is presenting this *Report* to industry and stakeholders as a consultation and seeking views on the proposals put forward. The closing date for responses is Friday 12th March.

Large sudden changes in supply and demand can cause the frequency of the GB electricity system to change. This *Report* and consultation sets out the parameters for how often, for how long and how large those frequency changes should be and sets out the criteria by which the ESO shall approach risks to frequency changes. The focus of the *Report* is to set out the right balance between risk and cost to the consumer to ensure the network is effectively and appropriately protected from frequency events for the following year.

This is the first time the process has been carried out and aims to be more transparent to industry and stakeholders, setting out clear and objective criteria by which the ESO balances cost and risk to ensure the end consumer receives efficient security of supply. As the energy system transitions to a low carbon system, the regular review of response, reserve and inertia holding will be important and this *Report* allows the ESO to review and manage emerging risks with our stakeholders.

The consultation seeks stakeholder views on 4 proposals. If these recommendations are implemented, our assessment indicates the risk of a frequency deviation exceeding:

- 48.8Hz is 1-in-270 years (Activation of Low Frequency Demand Disconnection)
- 49.2Hz is 1-in-22 years (Frequency Standard set out in System Operator Guidelines)
- 50.5Hz is 1-in-1,100 years (Frequency standard set out in the Grid Code)

The cost of frequency control in recent years has ranged from £275m - £360m [1]. The combined impact of the recommendations, delivery of the Accelerated Loss of Mains Change Programme and the introduction of Dynamic Containment is a reduction in risk. The recommendations will for the first time establish a clear benchmark which will allow us to measure the costs and risks of frequency control from now and into the future. The indicative cost for 2021/22 is £244m.

This *Report* also identifies the current value of the Accelerated Loss of Mains Change Programme and clarifies how the ESO manages the risk of inadvertent operation of the Loss of Mains protection. In addition, the *Report* confirms the value of the continuing growth of fast acting response through Dynamic Containment, a product launched in October 2020, and presents a suite of proposals which will reduce the requirement for the ESO to intervene in the market dispatch of power stations.

[1] Data source: NGESO Monthly Balancing Services Summary (MBSS)

2. Executive Summary

2.1. Purpose

The requirement for a *Frequency Risk and Control Report (Report)* has been newly introduced following the approval of Security and Quality of Supply Standards (SQSS) modification GSR027: Review of the NETS SQSS Criteria for Frequency Control that drive reserve, frequency response and inertia holding on the GB electricity system[2].

This *Report* sets out the assessment results of the operational frequency risks on the system, and has been prepared following the *Methodology*.

It includes an assessment of the magnitude, duration and likelihood of transient frequency deviations, forecast impact and the cost of securing the system and confirms which risks will or will not be secured operationally by *NGESO* under paragraphs 5.8, 5.11.2, 9.2 and 9.4.2 of the SQSS.

The final *Report* will be submitted to the *Authority* for approval on 01 April 2021. This document builds upon the *Policy* and *Methodology* document *NGESO* consulted on in January 2021.

2.2. Main Recommendation

The following proposals are recommendations to apply controls to prevent an event having a defined unwanted impact, where our assessment tells us these are good value, and not to apply controls where they are not good value. The proposals cover policies relating to the use of controls such as increasing or decreasing inertia (the electricity system's ability to dampen frequency changes) and automatic or manual actions. Examples of these controls are to curtail the output of large generation or interconnector infeed, or to curtail the amount of export on an interconnector. The various options and combinations of generation and interconnector losses have been grouped according to likelihood.

2.2.1. Proposals

Proposal 1: minimum national inertia requirement

- Continue with current *Policy*:
    - Minimum inertia at 140GVA.s

Proposal 2a: Frequency limit for different size infeed loss risks

- Don't apply individual loss risk controls to BMU-only, BMU+VS outage and BMU+VS intact events to keep resulting frequency deviations within 49.5Hz

[2] link to GSR027 documentation

Proposal 2b: individual loss risk controls

- Update current *Policy* to:
  - Apply individual loss risk controls to BMU-only events to keep resulting frequency deviations within 49.2Hz and 50.5Hz
  - Do not apply individual loss risk control to BMU+VS outage or BMU+VS intact events

In the *Report* these terms are used throughout: BMU (Balancing Mechanism Unit) is used to describe a generator, relevant collection of generators, or interconnector; planned network outages for maintenance or construction are captured under the term "outage"; and consequential generation losses due to the operation of Vector Shift protection are captured as "VS". The potential for the consequential operation of Rate of Change of Frequency (RoCoF) protection on distributed generation is included in each event category (see 6.2 Events for more detail).

2.3. Other recommendations

2.3.1. Proposals

Proposal 3: Dynamic Containment Low

- The new fast acting service, Dynamic Containment launched in October 2020, is delivering value today and continues to provide value into the future.
- The ESO should continue to increase its use of the Dynamic Containment low frequency service (Dynamic Containment Low) beyond 500MW in line with the anticipated pipeline

Proposal 4: ALoMCP

- The ALoMCP programme has been running for over a year and has already created significant value by removing nearly 10GW of Vector Shift protection settings. There is still a substantial volume of protection changes to be made to minimise the risk posed by the VS and RoCoF protection on distributed generation.
- The ALoMCP should continue during 2021 for both RoCoF and Vector Shift

2.4. Result of applying the proposals

By applying the above proposals to current *Policy*, the results are:

- total costs are indicated to be around £244m for the 2021/22
    - £240m for system-wide response and inertia controls
    - £ 4m for individual loss risk actions on BMU-only events
- the level of frequency risk on the system will be:

#	Deviation	Duration	Likelihood
H1	50.5 > Hz	Any	1-in-1,100 years
L1	49.2 ≤ Hz < 49.5	up to 60 seconds	2 times per year
L2	48.8 < Hz < 49.2	Any	1-in-22 years
L3	47.75 < Hz ≤ 48.8	Any	1-in-270 years

Table 1 – level of risk on the system

The cost of frequency control in recent years has ranged from £275m -£360m[3]. The combined impact of the recommendations, delivery of the Accelerated Loss of Mains Change Programme and the introduction of Dynamic Containment is a reduction in risk. The recommendations will for the first time establish a clear benchmark which will allow us to measure the costs and risks of frequency control from now and into the future. The indicative cost for 2021/22 is £244m.

2.5. Resulting changes to system operation

The key changes to current Policy resulting from this edition of the *Report* are:

- To consider allowing BMU-only *infeed* loss risks to cause a consequential RoCoF loss, if the resulting loss can be contained to 49.2Hz and 50.5Hz
- removing the tighter limit for smaller losses, and instead only applying the wider limit of 49.2Hz to all BMU-only *infeed* losses
- a number of BMU-only events which are secured under current *Policy* have been re-evaluated and are now more appropriately grouped with BMU+VS events, which due to their likely probabilities will no longer be secured.

2.6. Future considerations

Future editions of the *Frequency Risk and Control Report (FRCR)* will build on this edition to refine the analysis and include some events, loss risks, impacts and controls which are out of scope of this version as per the *Methodology*. Examples include simultaneous events, the impact of system conditions in the run-up to an event, multiple stages of LFDD, further investigation of high-frequency deviations etc. See **13. Future considerations** for details.

[3] Data source: NGESO Monthly Balancing Services Summary (MBSS)

2.7. Resulting policy

After adopting the proposals in the **12. Recommendations**, the proposed *Policy* can be summarised as:

	BMU-only	VS-only	BMU+VS outage	BMU+VS intact
Considered by policy	Yes	Yes	Yes	Yes
Mitigated in real-time	Yes	n/a[4]	No	No
Prevent consequential RoCoF loss	Allowing where controllable	n/a	No	No
Main control(s)	Frequency response and Reduce BMU loss size	Inertia	Reduce LoM loss size	Reduce LoM loss size
Additional control(s)	Inertia	Frequency response	n/a	n/a

Table 2 – overview of proposed NGESO policy

[4] as the VS-only risk is fully mitigated by minimum inertia policy

3. Contents

4. Overview

4.1. Suite of documents

There are three main documents in this process, which link together as follows:

Frequency Risk and Control Policy (Policy)[5]

- states current *National Grid Electricity System Operator* (*NGESO*) policy for frequency risks and controls, and
- provides a baseline for the first edition of the *Frequency Risk and Control Report*

It is written to provide clarity and transparency to how *NGESO* operates the system concerning frequency control. It is a necessary start-point for the process of developing the first edition of the *Frequency Risk and Control Report*.

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Frequency Risk and Control Report Methodology (Methodology)[6]

The *Methodology* document builds on the *Policy* document and lays out: what will be assessed in the April 2021 edition of the *Report*, how it will be assessed, and the format of the outputs. The *Methodology* comprises these steps:

Define inputs			
Impacts	Events & loss risks	Controls	Metrics for reliability vs. cost

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Conduct assessment

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Produce outputs		
Conclusions	Main recommendations	Other recommendations

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Frequency Risk and Control Report (Report)

This document is the *Report*. The *Report* sets out the assessment results of the operational frequency risks on the system and has been prepared per the *Methodology*.

It includes an assessment of the magnitude, duration and likelihood of transient frequency deviations, forecast impact and the cost of securing the system and confirms which risks will or will not be secured operationally by *NGESO* under paragraphs 5.8, 5.11.2, 9.2 and 9.4.2 of the SQSS.

The target date for the *Report* to be submitted to the *Authority* for approval is 01 April 2021[7].

[5] Frequency Risk and Control Policy - https://www.nationalgrideso.com/document/183426/download
[6] FRCR Methodology - https://www.nationalgrideso.com/document/185856/download
[7] NB: once approved by the *Authority*, the *ESO* will require an implementation period

4.2. Defined terms

This document contains technical terms and phrases specific to *transmission systems* and the Electricity Supply Industry. The meaning of some terms or phrases in this document may also differ from this commonly used. For this reason, defined terms from the SQSS have been identified in the text using *blue italics*.

5. Aim

5.1. Role of the Frequency Risk and Control Report

5.1.1. What is the Frequency Risk and Control Report?

The *Frequency Risk and Control Report*, as defined in the SQSS:

- sets out the results of an assessment of the operational frequency risks on the system
- includes an assessment of:
  - the magnitude, duration and likelihood of transient frequency deviations
  - the forecast impact
  - the cost of securing the system, and
  - confirms which risks will or will not be secured operationally by *NGESO* under paragraphs 5.8, 5.11.2, 9.2 and 9.4.2.

5.1.2. What is the Report trying to achieve?

In the context of system frequency, there are two key objectives:

- a reliable supply of electricity
- at an affordable cost

There is a balance between those objectives:

- higher reliability requirements result in higher direct costs to meet that requirement
- lower reliability requirements result in lower direct costs to meet that requirement but have higher indirect costs and impacts arising from the lower reliability requirement

These objectives are formalised through the Security and Quality of Supply Standards (SQSS), the *Frequency Risk and Control Report*.

This *Report* provides an assessment and recommendation on the right balance between the two competing objectives of reliability and cost, focusing on the risks, impacts and controls for managing the frequency.

5.1.3. What is meant by "reliability"?

The SQSS refers to *unacceptable frequency conditions* as a measure of reliability. This encompasses whether *transient frequency deviations* outside the range 49.5Hz to 50.5Hz are considered infrequent and tolerable. Whether frequency deviations are acceptable depends on the exact combination of three factors:

- how often they occur
- how long they last for, and
- how large they are

as each of these affects the **Impacts** of an event (see Ch **6.1**).

For example, larger or longer deviations that happen very rarely might be acceptable, but smaller or shorter deviations that occur very often might not.

The **Recommendations** (Ch **12**) proposes what should be considered reasonable as infrequent and tolerable for each of these criteria for *transient frequency deviations*.

5.1.4. What drives direct costs?

NGESO uses a set of *Ancillary Services* to control frequency deviations. Some are automatic, like frequency response. Others are manually dispatched, like reserve, the Balancing Mechanism, services to increase the inertia or services to pre-emptively decrease the size of potential loss risks. In this document, we refer to the *Ancillary Services* as “controls”.

The size, duration and likelihood of *transient frequency deviations* depend on:

- the size of the event that caused the frequency deviation
- how much of each of these controls are used, and the effectiveness of the controls

Scenario	Direct costs	Frequency deviations
Small event / more controls	Higher	Shorter, smaller, occur less often
Large event / fewer controls	Lower	Longer, larger, occur more often

The *Report* has considered relevant controls which *NGESO* currently has access to, or which *NGESO* anticipates having access to during 2021.

5.1.5. How to balance between reliability and cost?

The *Methodology* sets out an objective and transparent framework for *NGESO* to assess risks associated with frequency deviations, the events which could cause them, their size, the impacts they have, and the cost and mix of controls to mitigate them.

The assessment has been used to determine the appropriate balance between reliability and cost, as described in this *Report*.

Consultation and ongoing engagement with industry stakeholders is key to achieving this openly and transparently: the role of *NGESO* is to analyse the risks, impacts and controls, their impact on reliability and cost, and present a recommendation for where the appropriate balance might lie. This enables the *Authority* to make an informed decision on the right balance between the reliability of electricity supplies and cost to end consumers.

NGESO will then update their operational *Policy* and procurement of controls to implement the outcome. This can be found in **14. Appendix: Policy from April 2021**.

5.2. Scope of the Frequency Risk and Control Report

5.2.1. Scope of this edition

This first edition of the *Frequency Risk and Control Report* is focusing on the following key areas:

- establishing the *FRCR* process to deliver a clear, objective, transparent process for assessing reliability vs cost to ensure the best outcome for consumers
- assessing the risk from the inadvertent operation of Loss of Mains protection
- identifying quick, short-term improvements for reliability vs cost, including:
    - the delivery of the Dynamic Containment and Accelerated Loss of Mains Change programmes,
    - assessing the frequency standard that various size loss risks are held to, and
    - the impact of transmission network outages on radial connection loss risks

This *Report* covers system operation in 2021; the **13. Future considerations** section at the end of the *Report* outlines opportunities to address other considerations in future editions in future years.

NB: The FRCR is an assessment of all events across 2021, made using assumptions as to the likelihood and impact to system security based on the controls the ESO expects to have available. If there are circumstances whereby a specific event would lead to overall system risk being significantly different to the expected case, the ESO reserves the right to take actions to ensure that system risk remains in line with the risk appetite outlined in the FRCR.

5.2.2. Wider considerations out of scope of the FRCR

This *Report* is not intended to develop future controls or consider other topics such as wider system interactions, market design, whole-system costs and interactions with other markets. There are projects ongoing to address these wider industry considerations[8].

The *Report* may inform these developments and use them as inputs to future editions, but the *Report* is not the vehicle for these wider considerations.

The *Report* will be updated at least annually. As the wider industry projects develop, consideration will be given to whether they should be included and if so, how and when they will be included in future versions of the *Methodology*.

8 More information on the development of new solutions can be found in the Operability Strategy Report

6. Specific considerations for this edition

As described in the *Methodology*, this edition is considering the following:

6.1. Impacts

The *Report* has assessed four levels of impact to cover these considerations and allow comparison to historical performance:

#	Deviation	Duration	Relevance
H1	50.5 < Hz	Any	• Above current SQSS implementation • Plant performance prescribed in detail by Grid Code, but not often tested in real-life conditions
L1	49.2 ≤ Hz < 49.5	up to 60 seconds	• Current SQSS and SOGL implementation • Infrequent occurrence, but reasonable certainty over plant performance
L2	48.8 < Hz < 49.2	Any	• Beyond current SQSS implementation and SOGL, but without triggering LFDD • Plant performance prescribed in detail by Grid Code but not often tested in real-life conditions
L3	47.75 < Hz ≤ 48.8	Any	• First stage of LFDD

Table 3 – Impacts that have been assessed

These levels align to current frequency response holding policies but provide more detail for the likelihood of triggering Low-Frequency Demand Disconnection.

6.2. Events

6.2.1. Which events have been considered?

6.2.1.1. Categories of loss risk

One of the aims of this first edition is to bring transparency to our assessment of the risk from the inadvertent operation of Loss of Mains protection.

The *Report* covers the following three categories of loss risks, all of which are considered by current *Policy*:

BMU-only
- an event that disconnects one or more BMUs, and may or may not also cause a consequential RoCoF loss
  (no Vector Shift loss)

VS-only
- an event that causes a consequential Vector Shift (VS) loss and may or may not also cause a consequential RoCoF loss (no BMU loss)

BMU + VS
- an event that disconnects one or more BMUs and causes a consequential VS loss, and may or may not also cause a consequential RoCoF loss

As detailed in the *Policy* document: these events can be caused by *fault outages* of equipment on the *National Electricity Transmission System* (e.g. single circuits, double circuits, bar faults) and a *Loss of Power Infeed* or *Loss of Power Outfeed*.

NB: a number of BMU-only events which are secured under current Policy *have been re-evaluated and are now more appropriately grouped with BMU+VS events, which due to their likely probabilities will no longer be secured*

6.2.1.2. Impact of planned transmission network outages on radial connection loss risks

In some regions of the *National Electricity Transmission System*, loss risks exist on radial connections. In the case of a *double circuit* radial connection, as depicted in **Figure 1**, the likelihood of an event occurring increases during transmission network outage conditions.

This is because planned transmission networks outages leave these loss risks exposed to a *single circuit* fault, which is more likely than a *double circuit* fault.

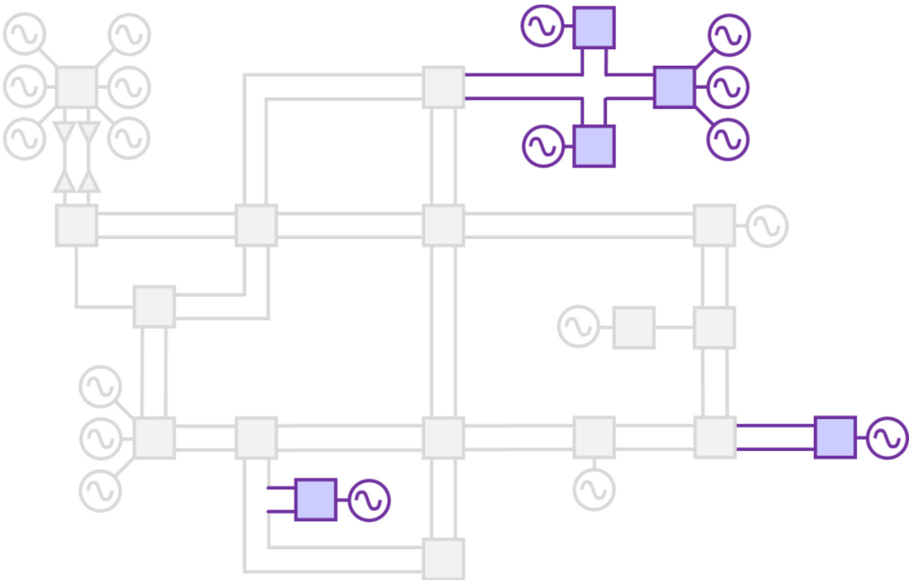

Figure 1 - potential double circuit faults on an illustrative network

The *Report* has investigated the materiality of the change in likelihood of these events under outage conditions, and what specific consideration (if any) should be given during these periods.

NB: any change to current Policy in this area would be likely to have an impact on the current Network Access Planning process

6.2.2. New loss risks

Several new loss risks are connecting to the system during the *Report* period (new interconnectors, new large offshore wind farms and new CCGT units).

New connections have been added to our event definitions if:

- they can cause a transient frequency deviation
- there are credible faults that can cause the loss of a single BMU or groups of BMU's and cause subsequent RoCoF events

The impact of new connections on system inertia has also been factored into the datasets used for the assessment, as outlined in the *Methodology*.

6.3. Controls

There are four main controls for mitigating *transient frequency deviations*:

- holding frequency response
- reducing BMU loss size
- reducing LoM loss size
- increasing inertia

The *Report* has investigated variations to the current *Policy* for all four controls:

- holding frequency response:
  → Dynamic Containment: anticipating this market to grow during the *Report* period
  → Frequency limit for different size loss risks: applying the wider limit of 49.2Hz to all infeed losses
- reducing BMU loss size: using controls to reduce the size of BMU-only and BMU+VS events
- reducing LoM loss size: anticipating a reduction as ALoMCP delivers during the reporting period
- increasing inertia: the effect of increasing the minimum-inertia limit.

6.3.1. Frequency response

The *Report* has investigated two variations to the current *Policy*:

6.3.1.1. Dynamic Containment and controlling consequential RoCoF losses

Current *Policy* is not to allow infeed losses to cause a consequential RoCoF loss, as the resulting losses have been too large and too quick to cover with existing response products, before the introduction of Dynamic Containment.

As the supply of Dynamic Containment increases and adds to the existing supply of Primary, Secondary and High-frequency response, the overall frequency response holding can begin to cover BMU+VS loss risks and any loss risk that also cause a consequential RoCoF loss.

The *Report* has looked the role Dynamic Containment can play in securing larger loss risks, including consequential RoCoF losses.

The assessment explicitly looks at allowing consequential RoCoF losses to occur, if they can be contained to the relevant **Impacts**: 50.5Hz, 49.5Hz, 49.2Hz, and 48.8Hz, with an expectation that *Policy* can be updated to allow infeed losses to cause a consequential RoCoF loss in circumstances where the overall loss can be secured.

6.3.1.2. Frequency limit for different size loss risks

Frequency Risk and Control Policy currently has two frequency limits for *infeed* losses, depending on their size:

- smaller losses (≤ 1000MW) are held to 49.5Hz
- larger losses (> 1000MW) are held to 49.2Hz

Historically, the amount of frequency response required to secure smaller losses to tighter limits had been approximately equal to the amount of frequency response needed to secure larger losses to wider limits. This has resulted in savings in balancing costs by allowing a wider limit for the less frequent, larger losses.

Decreasing system inertia means that the equality in the requirement often no longer holds, with the tighter limit for smaller losses, often the driving factor.

However, decreasing system inertia and the risk of consequential RoCoF losses has also meant that most loss risks over 700MW have been curtailed for a large proportion of the last few years.

The result of this is that system frequency has only dropped below 49.5 Hz once[9] since 2014. This is much less often than the historic expectation of four-times per year noted in the consultation responses to SQSS modification GSR015[10].

The *Report* has investigated the cost and impact of removing the tighter limit for smaller losses, and instead only applying the wider limit of 49.2Hz to all *infeed* losses and consequential RoCoF losses.

6.3.2. Reducing LoM loss size

The Accelerated Loss of Mains Change Programme (ALoMCP) is reducing the capacity of Distributed Energy Resources (DER) at risk of consequential loss of RoCoF and Vector Shift by de-sensitising the protection relays.

As the size of the consequential loss risks decreases, it will enable frequency response to cover BMU+VS loss risks and any loss risk that also causes a consequential RoCoF loss.

The *Report* has assessed benefit of further delivery of the ALoMCP.

[9] 09 August 2019
[10] https://www.nationalgrideso.com/document/15126/download

6.3.3. Reducing BMU loss size

This control is currently only applied to BMU-only loss risks under current *Policy*, as they represent good value. Current *Policy* is not to apply this control to BMU+VS risks, as they generally represent poor-value to mitigate[11].

As the volume of Dynamic Containment increases, it will allow more significant loss risks to be secured. Equally, as the LoM loss size goes down, the size of the largest loss risks will reduce. These two factors will change the cost vs risk balance, and so the *Report* has looked at reducing BMU loss size as a "targeted control" across both loss risks categories containing a BMU element.

6.3.4. Increasing inertia

6.3.4.1. Minimum inertia

The *Report* has looked at the potential benefit of increasing the minimum inertia limit above the current level of 140 GVA.s.

6.3.4.2. Inertia for VS-only loss risk

The inertia control for the "largest VS-only loss risk" has been applied, but does not result in any costs or change to overall risk. This is because delivery of Vector Shift relay changes through the Accelerated Loss of Mains Change Programme has significantly reduced the maximum VS-only loss risk size, from over 1000MW to below 700MW.

This means that the VS-only loss risks are fully covered by the minimum inertia policy, and so cannot pose a *transient frequency deviation* risk in 2021.

NB: VS-only loss risks are covered by system-wide controls.

[11] see **Policy > 6.2 Cost vs. Risk** for more information

6.4. Metrics

6.4.1. What principles can be applied?

At its simplest, for each level of impact:

- good value risks are likely to be those which are:
  - low cost to mitigate, or
  - likely to occur, or
  - which have a large impact

- poor value risks are likely to be those which are:
  - high cost to mitigate, or
  - unlikely to occur, or
  - which have a small impact

There is a whole spectrum of costs and likelihoods across each of the events, meaning a clear-cut judgement of the balance between reliability and cost can be challenging to reach for one event in isolation. Instead, the assessment must look at the total risk and total cost across all events.

Where risks are deemed to be of poor value and not actively mitigated, the backup measures prescribed through the Grid Code will act to minimise overall disruption to the system should they occur[12].

6.4.2. Which metrics have been applied?

Based on industry feedback to the *Methodology*, two metrics have been considered in this *Report* for assessing cost vs. risk. These are:

- how often each impact is expected to occur?
- what is the total cost of controls for managing frequency to the different **impact levels?**

[12] e.g. Low Frequency Demand Disconnection (LFDD) and Limited Frequency Sensitive Mode (LFSM)

7. Assessment

7.1. Current policy

The starting point for the assessment is current *Policy*, which can be summarised as:

	BMU-only	VS-only	BMU+VS
Considered by policy	Yes	Yes	Yes
Mitigated in real-time	Yes	Yes	No
Prevent consequential RoCoF loss	*Infeed*: Yes *Outfeed*: No	Yes	No
Main control(s)	Frequency response and Reduce BMU loss size	Inertia	Reduce LoM loss size
Additional control(s)	Inertia	Frequency response	n/a

Table 4 – Overview of current NGESO policy

7.2. Assessment steps

The *Methodology* describes in detail the steps in the assessment; below is a high-level overview of these steps:

Setup

Starting with current *Policy* as a baseline:

- Define a range of "Control scenarios"
- Define Events and loss risks

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For each "Control scenario"

Apply "system-wide" controls

These are the frequency response, inertia and LoM loss size controls. These are applied first as they affect all events and loss risks.

- Determine the required quantity of additional controls (with respect to the baseline)
- Calculate the cost of controls
- Calculate loss sizes
- Calculate baseline scenario risk

↓

Apply "individual loss risk" controls

This is the BMU loss size control and is applied after the "system-wide" controls to address any specific remaining risks

- Determine the required quantity of additional controls
- Calculate the cost of controls
- Calculate residual risk
- Calculate risk reduction

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Determine overall cost vs risk vs impact for the "Control scenario"

7.3. Control scenarios

7.3.1. Dataset

The assessment requires data to assess the cost versus risk of different scenarios, and has used historic scenarios adjusted for known or expected changes in 2021, as described in the *Methodology*.

Given the latest available information[13] on COVID-19 restriction roadmaps heading through spring and summer, the 2019 dataset (pre-COVID) has been used as the baseline for the *Report*. Where relevant, the 2020 dataset (COVID) has been used as a sensitivity to test the Proposals.

The impact of new connections on system inertia has also been factored in to the datasets used for the assessment, as outlined in the *Methodology*.

7.3.2. Scenarios

7.3.2.1. Baseline Control Scenario

The analysis has taken the expected position for frequency response volumes and loss of mains risks and assessed how the minimum inertia policy impacts the overall cost and baseline level of system risk. Specifically, this means:

- **Minimum inertia** maintained at 140GVA.s
- **Frequency response** per current *Policy*, with the addition of the expected pipeline of Dynamic Containment Low in 2021 (allowing larger losses including consequential RoCoF losses to be secured)
- **LoM capacity** as the forecast for 01 April 2021, for both RoCoF and Vector Shift

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[13] The analysis has been performed as a time series (at Settlement Period granularity) for the 2019 (pre-COVID) and 2020 (COVID) calendar years, adjusted for the expected changes in 2021, to allow a comparison for the impact of COVID restrictions on demand and consequential operation of the system in 2020.

The demand and inertia in the 2020 data set (COVID) is significantly reduced during the spring and summer period, with demands up to 20% lower than would have been expected without the impact of COVID restrictions.

In February 2021 COVID restriction are only reducing demand by 5%, a significantly smaller impact than in spring/summer 2021.

7.3.2.2. Individual loss risk controls

For many events, the system-wide controls are sufficient to prevent *transient frequency deviations*. Where they are not, 'individual loss risk controls' can be used to:

- prevent a consequential RoCoF loss from occurring by making sure the total BMU / Vector Shift loss stays within the Rate of Change of Frequency threshold, or
- still allow a consequential RoCoF loss but making sure the total BMU / Vector Shift / RoCoF loss stays within the level secured by the system-wide controls

The Report considers the total risk and total cost posed by each of the event categories:

- BMU-only
- BMU+VS intact
- BMU+VS outage

7.3.2.3. Other control scenarios

The Report looks at the following control scenarios, which feed into each of the Proposals in the subsequent chapters:

- Proposal 1: Minimum national inertia
  - looking at whether a change to the minimum inertia to increase from 140GVA.s to 160GVA.s should be adopted

- Proposal 2: Individual loss risk controls
  - looking at the frequency limit for different size infeed loss risks (49.5HZ Vs 49.2Hz), assessing whether to apply the wider limit of 49.2Hz to all infeed losses
  - looking at whether to apply separate loss risk controls to each of the event categories:
    - BMU-only
    - BMU+VS intact
    - BMU+VS outage

- Proposal 3: Dynamic Containment Low
  - looking at how changes in the level of Dynamic Containment Low can impact the cost vs risk balance

- Proposal 4: Reduce Loss of Mains
  - looking at how future delivery of the ALoMCP can impact the cost vs risk balance

Proposals 1 and 2 form the **Main Recommendation**. Proposals 3 and 4 form the **Other recommendations**.

8. Proposal 1: Minimum national inertia requirement

8.1. Aim

Proposal 1 assesses whether a change to the minimum inertia policy is beneficial.

8.2. Assessment

The assessment compares two scenarios:

- maintaining minimum inertia at 140GVA.s
- increasing minimum inertia at 160GVA.s

8.3. Results

Table 5 shows the difference in cost and risk for the 140GVA.s and 160GVA.s scenarios before any further individual loss risk controls are applied:

Scenario	140 GVA.s	160 GVA.s
Cost system-wide controls	£ 240m	£ 340m
Remaining risk: 48.8Hz	1-in-240 years	1-in-240 years
Remaining risk: 49.2Hz	1-in-7 years	1-in-7 years
Remaining risk: 49.5Hz	2 times per year	2 times per year
Remaining risk: 50.5Hz	1-in-3.6 years	1-in-3.6 years

Table 5 – 140GVA.s vs. 160GVA.s without further individual loss risk controls

Table 6 shows how this then changes if the current *Policy* to secure BMU-only risks is applied:

Scenario	140 GVA.s	160 GVA.s
System-wide controls cost	£ 240m	£ 340m
Individual loss risk controls cost	£ 27m	£ 20m
Total cost	£ 267m	£ 360m
Remaining risk: 48.8Hz	1-in-270 years	1-in-275 years
Remaining risk: 49.2Hz	1-in-22 years	1-in-22 years
Remaining risk: 49.5Hz	1-in-4.6 years	1-in-5 years
Remaining risk: 50.5Hz	1-in-1,100 years	1-in-1,100 years

Table 6 - 140GVA.s vs. 160GVA.s with individual loss risk controls for BMU-only events

*NB: **Appendix: Minimum inertia scenarios** contains full detail of the scenarios*

8.4. Conclusions

The assessment shows that increasing minimum inertia to 160GVA.s:

- would result in little to no benefit in risk reduction
- would result in a significant increase in cost

This would not present good value to the end consumer, and so is not recommended.

8.5. Proposal

Proposal 1: minimum national inertia requirement

- Continue with current *Policy*:
    - Minimum inertia at 140GVA.s

9. Proposal 2: Individual loss risk controls

9.1. Aim

Proposal 2 assesses whether applying the wider limit of 49.2Hz to all infeed losses is beneficial, as well as assessing whether to apply individual loss risk controls to each of the event categories:

- BMU-only
- BMU+VS outage
- BMU+VS intact

9.2. Assessment

9.2.1. Considerations

Current *Policy* applies individual loss risk controls to BMU-only events, but not to BMU+VS events in either intact or outage conditions. The assessment considers:

- not applying individual loss risk control to BMU-only events
  (i.e. only applying the system-wide response and inertia controls)
- continuing to apply individual loss risk control to BMU-only events
  (per current *Policy*)
- enhancing the *Policy* to also cover BMU+VS outage and BMU+VS intact events

9.2.2. Assumptions

The assessment is based on:

- **Proposal 1: Minimum national inertia** – 140 GVA.s minimum inertia

9.2.3. Value-order

The tables below rank the event categories from the best value to least value, determined by the cost of the required controls and the resulting reduction in the remaining risk at each of the different impact levels.

When assessing the impact levels, the controls for managing high frequency (50.5Hz) can be considered separately from low frequency (48.8Hz, 49.2Hz and 49.5Hz).

For low frequency, the System Operator Guidelines (SOGL) states that the maximum frequency deviations in GB shall be 0.8Hz. The assessment therefore considers the low frequency impacts in two steps:

- the risk of a frequency deviation exceeding 49.2Hz, corresponding to a 0.8Hz deviation under SOGL, and the equivalent risk of frequency reaching 48.8Hz and triggering the first-stage of the LFDD scheme, then
- the risk of a frequency deviation exceeding 49.5Hz, and the additional cost that would be required to apply extra control over and above those needed for 49.2Hz

9.3. Results

9.3.1. Impact level 49.2Hz and 48.8Hz

Analysis shows the remaining risk of low frequency events on the system is:

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 49.2Hz	Remaining risk 48.8Hz
Start point	n/a	n/a	1-in-7 years	1-in-240 years
BMU-only	£ 0.5m	£ 0.5m	1-in-22 years	1-in-270 years
BMU+VS outage	£ 2.3m	£ 2.8m	1-in-28 years	1-in-460 years
BMU+VS intact	£ 44.3m	£ 47.1m	1-in-31 years	1-in-600 years

Taking actions to secure BMU-only events costs £0.5m, and reduces the risk of a frequency deviation exceeding 49.2Hz from 1-in-7 years to 1-in-22 years. This is equivalent to the risk of a frequency deviation exceeding 48.8Hz being reduced from 1-in-240 years to 1-in-270 years.

For an additional £2.3m securing BMU+VS events in outage conditions to 49.2Hz further reduces the risk to 1-in-28 years (equivalent risk of 1-in-460 years for 48.8Hz).

Securing BMU+ VS intact events would cost a further £44.3 m to reduce the risk to 1-in-31 years. This is approximately fifteen times more than the spend to get the risk to 1-in-28 years for very minimal risk reduction and as such is deemed low value and not recommended.

9.3.2. Impact level 49.5Hz

After applying the system-wide controls, and in addition to the cost of securing the 49.2Hz risks, the remaining the risk of low frequency events on the system is:

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 49.5Hz
Start point	n/a	n/a	2 times per year
BMU-only	£ 23m	£ 23m	1-in-4.6 years
BMU+VS outage	£ 13m	£ 36m	1-in-5.6 years
BMU+VS intact	£ 330m	£ 366m	1-in-6.5 years

Taking actions to secure BMU-only events costs £23m and reduces the risk of a frequency deviation exceeding 49.5Hz from 2 times per year to 1-in-4.6 years.

For an additional £13m, securing BMU+VS events in outage conditions to 49.5Hz further reduces the risk to 1-in-5.6 years.

Securing BMU+ VS intact events would cost a further £330m to reduce the risk to 1-in-6.5 years.

9.3.3. Impact level 50.5Hz

After applying the system-wide controls, the remaining the risk of high frequency events on the system is:

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 50.5Hz
Start point	n/a	n/a	1-in-3.6 years
BMU-only	£ 3.8m	£ 3.8m	1-in-1,100 years
BMU+VS outage	£ 2.1m	£ 5.9m	1-in-2,800 years
BMU+VS intact	£ 21.2m	£ 27.1m	n/a

Taking control actions on BMU-only events costs £3.8m and reduces the risk of a frequency deviation exceeding 50.5Hz from 1-in-3.6 years to 1-in-1,100 years.

For an additional £2.1m securing BMU+VS events in outage conditions to 50.5Hz further reduces the risk to 1-in-2800 years.

Securing BMU+ VS events intact would cost a further £21.2m to reduce the risk entirely. This is ten times more than the spend to get the risk to 1-in-2800 years and as such is deemed low value and not recommended.

9.3.4. Summary

9.3.4.1. Without applying control to the 49.5Hz impact

Table 7 summarises the results above, applying individual loss risk control to 48.8Hz, 49.2Hz and 50.5Hz:

	System-wide controls	plus BMU-only	plus BMU+VS outage	plus BMU+VS intact
Extra	n/a	£ 4m	£ 5m	£ 65m
Total	£ 240m	£ 244m	£ 249m	£ 314m
48.8Hz	1-in-240 years	1-in-270 years	1-in-460 years	1-in-600 years
49.2Hz	1-in-7 years	1-in-22 years	1-in-28 years	1-in-31 years
49.5Hz	2 times per year	2 times per year	2 times per year	2 times per year
50.5Hz	1-in-3.6 years	1-in-1,100 years	1-in-2,800 years	n/a

Table 7 – effect of apply individual loss risk controls for each event category

9.3.4.2. Applying control to the 49.5Hz impact

Table 8 summaries the results above, applying individual loss risk control to 49.5Hz as well as 48.8Hz, 49.2Hz and 50.5Hz:

	System-wide controls	plus BMU-only	plus BMU+VS outage	plus BMU+VS intact
Extra	n/a	£ 27m	£ 18m	£ 395m
Total	£ 240m	£ 267m	£ 285m	£ 680m
48.8Hz	1-in-240 years	1-in-270 years	1-in-460 years	1-in-600 years
49.2Hz	1-in-7 years	1-in-22 years	1-in-28 years	1-in-31 years
49.5Hz	2 times per year	1-in-4.6 years	1-in-5.6 years	1-in-6.5 years
50.5Hz	1-in-3.6 years	1-in-1,100 years	1-in-2,800 years	n/a

Table 8 – effect of apply individual loss risk controls for each event category

9.4. Conclusions

9.4.1.1. Frequency limit for different size infeed loss risks (49.2Hz vs. 49.5Hz)

The cost-risk benefit of securing the loss risks to 49.5Hz rather than 49.2Hz is as follows:

- Taking actions to secure BMU-only events costs £23m and reduces the risk of a frequency deviation exceeding 49.5Hz from 2 times per year to 1-in-4.6 years.
- For an additional £13m, securing BMU+VS events in outage conditions to 49.5Hz further reduces the risk from 1-in-4.6 years to 1-in-5.6 years.
- Securing BMU+ VS intact events would cost a further £330m to reduce the risk from 1-in-5.6 years to 1-in-6.5 years.

The historic expectation has been for transient frequency deviations below 49.5Hz to occur around four times per year. As the expected rate is only two times per year without applying controls to BMU-only, BMU+VS outage or BMU+VS intact events, they all represent poor value for money.

9.4.1.2. Across the 48.8Hz, 49.2Hz and 50.5Hz impacts

Across these impacts (excluding 49.5Hz):

- applying individual loss risk controls to the BMU-only events all provide good value for money, at an indicative cost of £4m in 2021 to reduce the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in-240 years to 1-in-270 years
  - 49.2Hz from 1-in-7 years to 1-in-22 years
  - 49.5Hz remains at 2 times per years
  - 50.5Hz from 1-in-3.6 years to 1-in-1,100 years

- applying individual loss risk controls to the BMU+VS outage events provides less value, at an indicative additional cost of £5m in 2021 to reduce the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in-270 years to 1-in-460 years
  - 49.2Hz from 1-in-22 years to 1-in-28 years
  - 49.5Hz remains at 2 times per years
  - 50.5Hz from 1-in-1,100 years to 1-in-2,800 years

- Applying the individual loss risk controls to the BMU+VS intact events are poor value, at an indicative additional cost of £65m in 2021 to reduce the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in- 460 years to 1-in-600 years
  - 49.2Hz from 1-in-28 years to 1-in-31 years
  - 49.5Hz remains at 2 times per years
  - 50.5Hz from 1-in-2,800 years to being fully mitigated

Securing BMU-only events to 49.2Hz and 50.5Hz is good value for money, BMU+VS outage events are lower value for money, and the BMU+VS intact events are poor value for money.

*NB: **Appendix: Individual loss risk controls** summarises the results if 49.5Hz was also secured*

9.5. Proposals

Proposal 2a: Frequency limit for different size infeed loss risks

- Don’t apply individual loss risk controls to BMU-only, BMU+VS outage and BMU+VS intact events to keep resulting frequency deviations within 49.5Hz

Proposal 2b: individual loss risk controls

- Update current *Policy* to:
    - Apply individual loss risk controls to BMU-only events to keep resulting frequency deviations within 49.2Hz and 50.5Hz
    - Do not apply individual loss risk control to BMU+VS outage or BMU+VS intact events

10. Proposal 3: Dynamic Containment Low

10.1. Aim

Proposal 3 assesses how changes in the level of Dynamic Containment Low can impact the cost vs. risk balance.

10.2. Assessment

10.2.1. Considerations

The assessment considers two scenarios:

- 500MW of Dynamic Containment Low
- growing Dynamic Containment Low further with the anticipated MW pipeline

The anticipated pipeline reaches 500MW in May 2021 and 900MW in July 2021. This is a best view based on the information the ESO has at the time of writing, and so is subject to change.

This informs whether it is valuable to procure more than 500MW of Dynamic Containment Low in 2021.

10.2.2. Assumptions

The assessment is based on:

- **Proposal 1: Minimum national inertia** – 140 GVA.s minimum inertia, and
- **Proposal 2: Individual loss risk controls** – applying individual loss risk controls to BMU-only events for 49.2Hz and 50.5Hz, but not applying individual loss risk control to BMU+VS outage or BMU+VS intact events

10.3. Results

Scenario	DC at 500MW	DC Pipeline
System-wide controls cost	£ 220m	£ 240m
Individual loss risk controls cost	£ 8m	£ 4m
Total cost	£ 228m	£ 244m
Remaining risk: 48.8Hz	1-in-63 years	1-in-270 years
Remaining risk: 49.2Hz	1-in-10 years	1-in-22 years
Remaining risk: 49.5Hz	3 times per year	2 times per year
Remaining risk: 50.5Hz	1-in-1,100 years	1-in-1,100 years

Table 9 – effect of different levels of Dynamic Containment Low

10.4. Conclusions

Growing the Dynamic Containment Low pipeline in 2021:

- reduces the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in-63 years to 1-in-270 years
  - 49.2Hz from 1-in-10 years to 1-in-22 years
  - 49.5Hz from 3 times per year to 2 times per year
- results in an increase total costs by £16m from £ 228m to £ 244m
  - system-wide controls costs increase by £20m
  - this is offset by a decrease in the cost of individual loss risk controls by £4m

Overall, growing the Dynamic Containment Low pipeline in 2021 represents good value for money.

It should also be noted that a wider benefit of growing the pipeline is to reduce in the scale of intervention the ESO must take in market dispatch through trades and Balancing Mechanism actions, moving those to the system-wide response and inertia controls and competitive markets.

10.5. Proposal

Proposal 3: Dynamic Containment Low

- The new fast acting service, Dynamic Containment launched in October 2020, is delivering value today and continues to provide value into the future.
- The ESO should continue to increase its use of the Dynamic Containment low frequency service (Dynamic Containment Low) beyond 500MW in line with the anticipated pipeline

11. Proposal 4: Reduce Loss of Mains capacity

11.1. Aim

Proposal 4 assesses how future delivery of the ALoMCP can impact the cost vs. risk balance. This informs the value of continued delivery of RoCoF and Vector Shift relay changes through the ALoMCP and their resultant reduction to system risk in 2021.

11.2. Assessment

11.2.1. Considerations

The assessment considers three scenarios:

- no changes to the Loss of Mains risk baseline for 2021
- a 50% reduction to the Vector Shift risk but no change to the RoCoF baseline for 2021
- a 50% reduction to the Vector Shift risk and a 50% reduction to the RoCoF risk for 2021.

11.2.2. Assumptions

The assessment is based on:

- **Proposal 1: Minimum national** inertia – 140 GVA.s minimum inertia, and
- **Proposal 2: Individual loss risk controls** – applying individual loss risk controls to BMU-only events for 49.2Hz and 50.5Hz, but not applying individual loss risk control to BMU+VS outage or BMU+VS intact events, and
- **Proposal 3: Dynamic Containment Low** – continuing to grow the Dynamic Containment Low pipeline beyond 500MW

11.3. Results

Scenario	Remaining capacity		
	100% Vector Shift 100% RoCoF	50% Vector Shift 100% RoCoF	50% Vector Shift 50% RoCoF
Remaining risk: 48.8Hz	1-in-270 years	1-in-400 years	1-in-16,000 years
Remaining risk: 49.2Hz	1-in-22 years	1-in-25 years	1-in-275 years
Remaining risk: 49.5Hz	2 times per year	2 times per year	1-in-1.4 years
Remaining risk: 50.5Hz	1-in-1,100 years	1-in-850 years	1-in-700 years

Table 10 – effect of reducing LoM capacity

NB: the increase in the 50.5Hz risks associated with the reduced capacity scenarios is because the now smaller RoCoF and Vector Shift (generation) losses have a lower offsetting impact against the initial demand loss

11.4. Conclusions

Consequential RoCoF and Vector Shift loss are a key driver of system risk. Continued delivery of the ALoMCP during 2021 for both RoCoF and Vector Shift provides a significant reduction in the low frequency 48.8Hz, 49.2Hz and 49.5Hz risks.

These risk levels are achieved by a combination of Dynamic Containment and delivery of the ALoMCP. It is important to note that there will be an enduring requirement and cost of holding additional Dynamic Containment until a one-off change to relays are made. At current prices, 1MW of Dynamic Containment Low costs around £150k per year. The average cost of changing 1MW of capacity under the ALoMCP has been under £2k as a one-off cost.

Therefore, the ALoMCP should continue to pursue RoCoF and Vector Shift relay changes in 2021.

NB: This analysis is only valid for 2021, and does not consider the likely increasing future value of continued relay change. The electricity system is in transition, with larger infeed loss risks connecting to the system and lower inertia periods anticipated more often. Consequential RoCoF and Vector Shift losses will continue to be a key driver of system risk as a result. Future editions of the Report will continue to assess these risks.

11.5. Proposal

Proposal 4: ALoMCP

- The ALoMCP programme has been running for over a year and has already created significant value by removing nearly 10GW of Vector Shift protection settings. There is still a substantial volume of protection changes to be made to minimise the risk posed by the Vector Shift and RoCoF protection on distributed generation.
- The ALoMCP should continue during 2021 for both RoCoF and Vector Shift.

12. Recommendations

The following proposals are recommendations to apply controls to prevent an event having a defined unwanted impact, where our assessment tells us these are good value, and not to apply controls where they are not good value. The proposals cover policies relating to the use of controls such as increasing or decreasing inertia (the electricity system's ability to dampen frequency changes) and automatic or manual actions. Examples of these controls are to curtail the output of large generation or interconnector infeed, or to curtail the amount of export on an interconnector. The various options and combinations of generation and interconnector losses have been grouped according to likelihood.

12.1. Main Recommendation

12.1.1. Proposals

12.1.1.1. Minimum inertia

Conclusions

The assessment shows that increasing minimum inertia to 160GVA.s:

- would result in little to no benefit in risk reduction
- would result in a significant increase in cost

This would not present good value to the end consumer, and so is not recommended.

Proposal 1: minimum national inertia requirement

- Continue with current *Policy*:
  - Minimum inertia at 140GVA.s

12.1.1.2. Individual loss risk controls

Conclusions

The historic expectation has been for transient frequency deviations below 49.5Hz to occur four times per year. As the expected rate is only two times per year without applying controls to BMU-only, BMU+VS outage or BMU+VS intact events, they all represent poor value for money.

Securing BMU-only events to 49.2Hz and 50.5Hz is good value for money, BMU+VS outage events are lower value for money, and the BMU+VS intact events are poor value for money.

Proposal 2a: Frequency limit for different size infeed loss risks

- Don't apply individual loss risk controls to BMU-only, BMU+VS outage and BMU+VS intact events to keep resulting frequency deviations within 49.5Hz

Proposal 2b: individual loss risk controls

- Update current *Policy* to:
    - Apply individual loss risk controls to BMU-only events to keep resulting frequency deviations within 49.2Hz and 50.5Hz
    - Do not apply individual loss risk control to BMU+VS outage or BMU+VS intact events

The term BMU (Balancing Mechanism Units) is used to describe a generator, relevant collection of generators, or interconnector. Planned outages for maintenance or construction ("outage") and consequential generation losses due to the operation of Vector Shift protection (VS) or Rate of Change of Frequency (RoCoF) protection on distributed generation were found to be key groupings for this assessment.

12.2. Other recommendations

12.2.1. Proposals

12.2.1.1. Dynamic Containment

Conclusions

Growing the Dynamic Containment Low pipeline in 2021 represents good value for money, and has a wider benefit reducing the scale of intervention the ESO must take in market dispatch through trades and Balancing Mechanism actions.

Proposal 3: Dynamic Containment Low

- The new fast acting service, Dynamic Containment launched in October 2020, is delivering value today and continues to provide value into the future.
- The ESO should continue to increase its use of the Dynamic Containment low frequency service (Dynamic Containment Low) beyond 500MW in line with the anticipated pipeline

12.2.1.2. Loss of Mains

Conclusions

Consequential RoCoF and Vector Shift loss are a key driver of system risk. Continued delivery of the ALoMCP during 2021 for both RoCoF and Vector Shift provides a significant reduction in the low frequency 48.8Hz, 49.2Hz and 49.5Hz risks.

Proposal 4: ALoMCP

- The ALoMCP programme has been running for over a year and has already created significant value by removing nearly 10GW of Vector Shift protection settings. There is still a substantial volume of protection changes to be made to minimise the risk posed by the Vector Shift and RoCoF protection on distributed generation.

- The ALoMCP should continue during 2021 for both RoCoF and Vector Shift.

12.3. Result of applying the proposals

By applying the above proposals to current *Policy*, the results are:

- total costs are indicated to be around £244m for 2021/22
  - £240m for system-wide response and inertia controls
  - £4m for individual loss risk actions on BMU-only events
- the level of frequency risk on the system will be:

#	Deviation	Duration	Likelihood
H1	50.5 > Hz	Any	1-in-1,100 years
L1	49.2 ≤ Hz < 49.5	up to 60 seconds	2 times per year
L2	48.8 < Hz < 49.2	Any	1-in-22 years
L3	47.75 < Hz ≤ 48.8	Any	1-in-270 years

Table 11 – level of risk on the system

The cost of frequency control in recent years has ranged from £275m - £360m [14]. The combined impact of the recommendations, delivery of the Accelerated Loss of Mains Change Programme and the introduction of Dynamic Containment is a reduction in risk. The recommendations will for the first time establish a clear benchmark which will allow us to measure the costs and risks of frequency control from now and into the future. The indicative cost for 2021/22 is £244m.

12.4. Resulting changes to system operation

The key changes to current Policy resulting from this edition of the *Report* are:

- To consider allowing BMU-only *infeed* loss risks to cause a consequential RoCoF loss, if the resulting loss can be contained to 49.2Hz and 50.5Hz
- removing the tighter limit for smaller losses, and instead only applying the wider limit of 49.2Hz to all BMU-only *infeed* losses
- a number of BMU-only events which are secured under current *Policy* have been re-evaluated and are now more appropriately grouped with BMU+VS events, which due to their likely probabilities will no longer be secured

[14] Data source: NGESO Monthly Balancing Services Summary (MBSS)

12.5. Stakeholder impacts

12.5.1. Balancing market participants

As well as the direct benefit of reduced risk, growing the Dynamic Containment pipeline will also reduce the scale of intervention the ESO must take in market dispatch through trades and Balancing Mechanism actions.

12.5.2. Distributed Energy Resources

Distributed Energy Resources who have yet to change their Loss of Mains protection setting to comply with the latest standards will have an increase likelihood of their protection being activated due to events on the *National Electricity Transmission System*.

12.5.3. Transmission Network Owners

As proposal 2 is to maintain current *Policy*, there should be no impact on the current Network Access Planning process.

13. Future considerations

There are a number of events, loss risks, impacts and controls which are not explicitly considered in this edition of the *Report*. They will be prioritised for future inclusion in future reports, based on consultation with the industry and the *Authority*.

Examples include:

13.1. Events and loss risks

Simultaneous events	• as the new frequency response services come on line, being able to assess the value of securing simultaneous events, and also defining what would be classed as co-incident and simultaneous losses *e.g. coincident faults in parts of the network* • assessing simultaneous losses will require a step-change in analysis, due to the scale of the data processing and complexity of how events can and can't interact *e.g. 300 individual events become 44,850 pairs of simultaneous events* • once the *Report*, *Methodology* and *NGESO* processes are established through the first edition, it will be possible to expand the analysis
Other events driven by planned transmission network outages	• the change in the likelihood of existing events or new events created during outages on the *NETS*, other than those outages already considered by the *Methodology*
Weather conditions	• the change in the likelihood of events during *adverse conditions* • the key complexity is how to quantify the increase in risk
New causes of events	• such as Active Network Management schemes (AMNs), single control points for multiple-BMUs, IP risks • more work is required to understand and quantify these events
Generation connections	• assets owned by generators that connect them to the *NETS*, but which are not covered by the SQSS *e.g. short double circuit routes from a power station to a substation*
New causes of distributed resource losses	• any new causes that come to light as the power system evolves

New infeed and outfeed losses

- connections in coming years, including new interconnectors, offshore wind, and nascent technologies
- the key question to address is how to forecast the running-pattern and reliability of new connections

Impact of system conditions in the run-up to an event

- how this impacts on the ability of the system to cope with events
  e.g. more onerous starting frequency, sustained high or low frequency and the impact on energy-limited controls

13.2. Impacts

Multiple stages of LFDD

- if events could cause more than one stage of LFDD, and how often this could happen

Further investigation of high frequency deviations

- historically the focus has been on low frequency, but as more large *outfeed* losses connect this may need to change

Further investigations of frequency deviations closer to 50 Hz

- how smaller deviations[15] impact users, and how often they should be allowed to occur

13.3. Controls

Response and Reserve

- future services developed under the Response and Reserve roadmap

Inertia

- future stages of the Stability Pathfinder
- reducing the level of minimum inertia below 140GVA.s

ALoMCP delivery

- cost and risk reduction achievable through full delivery of the programme

[15] of the order of operational limits (49.8Hz to 50.2Hz)

13.4. Metrics

Other approaches to valuing cost vs. risk	• whether there are other projects, initiative or research which can help to inform the metrics and the tolerability of events to end consumers *e.g. the Black Start Task Force*
Ongoing updates	• regularly updating the metrics to incorporate the effect of changes in the value of security of supply as electricity demand changes *e.g. due to the electrification of heat, electric vehicles*
Implementation	• the time and costs associated with implementing a change in policy

13.5. Analysis and data

Improvements in statistical data inputs	• whether there is the opportunity for better quality or more accurate input data on the probability of the various types of faults, and how to reflect any uncertainties • whether to model a range of possible weather scenarios to understand the variance this introduces
Consideration of costs other than BSUoS charges	• whether to assess the wider costs of procuring controls over and above the direct Balancing Use of System (BSUoS) charges

14. Appendix: Policy from April 2021

14.1. Summary of policy

After adopting the proposals in the **12. Recommendations**, the proposed *Policy* can be summarised as:

	BMU-only	VS-only	BMU+VS outage	BMU+VS intact
Considered by policy	Yes	Yes	Yes	Yes
Mitigated in real-time	Yes	n/a[16]	No	No
Prevent consequential RoCoF loss	Allowing where controllable	n/a	No	No
Main control(s)	Frequency response and Reduce BMU loss size	Inertia	Reduce LoM loss size	Reduce LoM loss size
Additional control(s)	Inertia	Frequency response	n/a	n/a

Table 12 – Overview of proposed NGESO policy

[16] as the VS-only risk is fully mitigated by minimum inertia policy

14.2. Specific policy

After adopting the proposals in the **12. Recommendations**, the specific *Policy* would be:

14.2.1. Frequency response

NGESO will:

a) Infeed losses

- prevent BMU-only and VS-only *infeed* losses causing a frequency deviation below 49.2Hz and restore frequency above 49.5Hz within 60s

b) Demand losses

- prevent all BMU-only *outfeed* losses causing a frequency deviation above 50.5Hz
- prevent the loss of Super Grid Transformer supplies to Distribution Networks causing a frequency deviation above 50.5Hz[17]

  NB: VS-only losses can't cause outfeed *losses, only* *infeed losses*

14.2.2. Inertia

NGESO will:

a) Minimum inertia

- maintain system inertia at or above 140 GVA.s

  → this prevents all BMU-only, VS-only and BMU+VS loss risks up to approximately 700MW from causing a consequential RoCoF loss[18]

b) Largest VS-only loss risk

- ensure system inertia is maintained at or above the level that will prevent the largest VS-only loss from causing a consequential RoCoF loss

14.2.3. Reduce Loss of Mains loss size

NGESO will;

Accelerated Loss of Mains Change Programme (ALoMCP)

- update operational tools with latest programme delivery, as a reduction against the initial baseline capacity estimate at the start of the programme

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17 these are a loss of power outfeed and are typically smaller than 560MW
18 for some loss risks, the inertia lost with the event means the threshold is slightly below 700MW

14.2.4. Reduce BMU loss size

NGESO will;

a. Infeed loss risks

- consider allowing BMU-only *infeed* loss risks to cause a consequential RoCoF loss, where the resulting loss can be contained to 49.2Hz
  - → if not, take bids to reduce the BMU-only *infeed* loss to prevent a consequential RoCoF loss

b. Outfeed loss risks

- consider allowing BMU-only *outfeed* loss risks to cause a consequential RoCoF loss, as the two losses will partially offset each other[19]
  - → this is only permissible if the resulting high frequency and/or low frequency deviations are acceptable
  - → if they are not acceptable, then do not let BMU-only *outfeed* losses cause a consequential RoCoF loss, by taking offers to reduce the demand loss

14.2.5. Variations to this policy

There are specific, limited variations to these policies based on technical, probabilistic and economic grounds. This includes additional actions where appropriate during times of increased system risk, such as during severe weather, and exceptions where risks cannot feasibly occur[20].

The *FRCR* is an assessment of all events across 2021, made using assumptions as to the likelihood and impact to system security based on the controls the *ESO* expects to have available. If there are circumstances whereby a specific event would lead to overall system risk being significantly different to the expected case, the *ESO* reserves the right to take actions to ensure that system risk remains in line with the risk appetite outlined in the *FRCR*.

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[19] the BMU-only *outfeed* loss would make frequency rise, but the consequential RoCoF loss would make the frequency fall, so the net effect of the combined loss is smaller

[20] e.g. due to the configuration of a BMU making the loss of the whole BMU at once not credible

15. Appendix: Minimum inertia scenarios

15.1. Minimum inertia at 140GVA.s

15.1.1. System-wide controls

The indicative total cost of the system-wide response and inertia controls is approximately £250m.

15.1.2. Individual loss risk and impacts

After applying the system-wide controls, the remaining risk on the system is:

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 50.5Hz
Start point	n/a	n/a	1-in-3.6 years
BMU-only	£ 3.6m	£ 3.6m	1-in-1,100 years
BMU+VS outage	£ 2.1m	£ 5.7m	1-in-2,800 years
BMU+VS intact	£ 21.0m	£ 26.7m	n/a

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 49.2Hz	Remaining risk 48.8Hz
Start point	n/a	n/a	1-in-7 years	1-in-240 years
BMU-only	£ 0.5m	£ 0.5m	1-in-22 years	1-in-270 years
BMU+VS outage	£ 2.3m	£ 2.8m	1-in-28 years	1-in-460 years
BMU+VS intact	£ 44.3m	£ 47.1m	1-in-31 years	1-in-600 years

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 49.5Hz
Start point	n/a	n/a	2.4 times per year
BMU-only	£ 23m	£ 23m	1-in-4.6 years
BMU+VS outage	£ 15m	£ 38m	1-in-5.6 years
BMU+VS intact	£ 380m	£ 418m	1-in-6.5 years

15.2. Minimum inertia at 160GVA.s

15.2.1. System-wide controls

In this scenario, the total cost of the system-wide response and inertia controls is approximately £340m.

15.2.2. Individual loss risk and impacts

After applying the system-wide controls, the remaining risk on the system is:

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 50.5Hz
Start point	n/a	n/a	1-in-3.6 years
BMU-only	£ 3.7m	£ 3.7m	1-in-1,100 years
BMU+VS outage	£ 2.2m	£ 5.9m	1-in-2,900 years
BMU+VS intact	£ 22.0m	£ 27.9m	n/a

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 49.2Hz	Remaining risk 48.8Hz
Start point	n/a	n/a	1-in-7 years	1-in-240 years
BMU-only	£ 0.5m	£ 0.5m	1-in-22 years	1-in-275 years
BMU+VS outage	£ 2.1m	£ 2.7m	1-in-28 years	1-in-470 years
BMU+VS intact	£ 43.0m	£ 45.6m	1-in-31 years	1-in-610 years

Event category	Cost to mitigate (per year)	Cumulative cost (per year)	Remaining risk 49.5Hz
Start point	n/a	n/a	2 times per year
BMU-only	£ 16m	£ 16m	1-in-5 years
BMU+VS outage	£ 14m	£ 30m	1-in-6 years
BMU+VS intact	£ 321m	£ 351m	1-in-7 years

16. Appendix: Individual loss risk controls

16.1. Across all impacts (48.8Hz, 49.2Hz, 49.5Hz and 50.5Hz)

Across each of the impacts:

- applying individual loss risk controls to the BMU-only events all provide good value for money, at an indicative cost of £27m in 2021 to reduce the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in-240 years to 1-in-270 years
  - 49.2Hz from 1-in-7 years to 1-in-22 years
  - 49.5Hz from 2 times per years to 1-in-4.6 years
  - 50.5Hz from 1-in-3.6 years to 1-in-1,100 years

- applying individual loss risk controls to the BMU+VS outage events provides less value, at an indicative additional cost of £18m in 2021 to reduce the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in-270 years to 1-in-460 years
  - 49.2Hz from 1-in-22 years to 1-in-28 years
  - 49.5Hz from 1-in-4.6 years to 1-in-5.6 years
  - 50.5Hz from 1-in-1,100 years to 1-in-2,800 years

- Applying the individual loss risk controls to the BMU+VS intact events are poor value for money, at an indicative additional cost of £395m in 2021 to reduce the risk of a frequency deviation exceeding:
  - 48.8Hz from 1-in- 460 years to 1-in-600 years
  - 49.2Hz from 1-in-28 years to 1-in-31 years
  - 49.5Hz from 1-in-5.6 years to 1-in-6.5 years
  - 50.5Hz from 1-in-2,800 years to being fully mitigated