Frequency Risk and Control Report

Security & Quality of Supply Standards

Methodology and Assessment – For approval

Simultaneous events

March 2022

nationalgridESO

Contents

1. Foreword

Following the power disruption on 09 August 2019, the Electricity System Operator (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 requirement for the ESO to produce a Frequency Risk and Control Report (FRCR) and consult with industry on the methodology and assessment presented in the report.

The ESO consulted on FRCR 2022 between 21 February and 4 March 2022. A webinar was held on 28 February to answer any questions relating to the consultation. The ESO received 4 responses to the consultation with all 4 agreeing with the overall proposal that taking additional actions to secure all simultaneous events does not represent good value for money for consumers.

A summary of the consultation responses can be found in section 7.2.

Large sudden changes in supply and demand can cause the frequency of the GB electricity system to change. This 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 manage such risks.

The 2022 edition of the FRCR assesses the costs and benefits of securing against the risk of simultaneous events, as recommended by Ofgem's investigation into the power disruption on 9th August[1]. 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. The report aims to improve transparency across 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 together with our stakeholders.

The cost of frequency control in recent years has ranged from £275m - £360m. The combined impact of the recommendations, delivery of the Accelerated Loss of Mains Change Programme (ALoMCP) and the introduction of Dynamic Containment (DC) has reduced system frequency risk. This report confirms the value of these work programmes and presents our proposals relating to securing simultaneous events on the system.

[1] https://www.ofgem.gov.uk/publications/investigation-9-august-2019-power-outage

2. Executive summary

The requirement for a Frequency Risk and Control Report (FRCR) was 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'. FRCR 2021 created a baseline for cost versus risk when managing frequency.

Through the implementation of our frequency strategy, combining the impact of the Accelerated Loss of Mains Change Programme (ALoMCP), increasing Dynamic Containment (DC) volumes and the 2021 FRCR policy, there has been a **reduction in the risk of low frequency demand (LFDD) events** on the system since the events of 9th August 2019. For comparison if the same scenario that occurred on 9th August were to happen again, the Ancillary Services now available mean that a low frequency demand disconnection event would be avoided. This is explained further in section 6.5

This report covers the remaining action from 9th August which was to consider whether there is consumer benefit of securing simultaneous events. It also assesses whether the existing policy (approved in 2021) still delivers the best value for the consumer. It should be recognised that simultaneous events can range from two relatively small faults to the simultaneous tripping of the two largest systems infeeds. **Existing policy already covers 74% of simultaneous events** on the system when securing to 49.2Hz. However, given the potential size of the largest simultaneous events on the system, **ESO response costs would have to increase by a factor of ~3 to secure for the remaining 26% of simultaneous events** (compared to the implementation of 2021 policy). In addition, the ESO would also be required to increase reserve holdings to stabilise the system after a simultaneous event. This would further increase ESO costs by a combined factor of ~6 to secure for all simultaneous events.

For the additional spend on response costs to be considered good value for money, the peak simultaneous event would need to occur once every 2.5 years. There have been 2 unsecured simultaneous events in the past 20 years that have led to a low frequency demand disconnection event, suggesting that, on average, such events occur once every ten years. As such, **we do not currently consider the cost of securing for simultaneous events to represent good value for money for end consumers**, based on the metrics set out in section 3.5 of this report.

Aside from the significant costs associated with securing simultaneous events (against the frequency with which they are likely to occur), there are also other impacts which are important to consider when assessing the benefits to consumers. Securing against all simultaneous events would require a significant increase in DC capacity and up to 2.7GW would be needed. At present, there are insufficient assets on the system to provide this response and is a considerable increase from current capacity volumes.

Continuation of 2021 policy (including simultaneous events) leaves a residual risk[2] of:

- 1 in 14-year risk of a 49.2Hz event,
- 1 in 28-year risk of a 48.8Hz event.

The total indicative cost of DC response services through implementing current policy is £190M per annum. To secure simultaneous events an additional £370M spend is required on this service meaning the total DC response cost would be £550M (or an increase by a factor of ~3 as above).

Therefore, we do not currently consider the additional costs to mitigate the further risk of simultaneous events to represent good value for the end consumer under the FRCR framework and do not recommend changing the existing FRCR policy to secure for simultaneous events. We will keep the impacts of simultaneous events under review.

[2] It should be noted that FRCR 2021 did not include simultaneous events in the system background risk profile while we have this year. This means that the residual risk quoted here is not comparable to the previous residual risks quoted in FRCR 2021 as it is on a different basis. See Appendix 9.4 for the residual risk in 2022 on the same risk background (without simultaneous events) as calculated in FRCR 2021.

3. Background

3.1 Purpose

The requirement for a Frequency Risk and Control Report was 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 in 2020’. There are three main documents in this process which link together as follows:

Frequency Risk and Control Policy

Current Policy resulting from the approved 2021 FRCR is:

- Apply individual loss risk controls to BMU-only events to keep resulting frequency deviations within 49.2Hz and 50.5Hz
- To allow BMU-only infeed loss risks to cause a consequential RoCoF loss, if the resulting loss can be contained to 49.2Hz and 50.5Hz
- Do not apply individual loss risk control to BMU+VS outage or BMU+VS intact events

Frequency Risk and Control Report Methodology

The methodology sets out what will be assessed, how it will be assessed and the format of the outputs. The methodology inputs include: impacts, events and loss risks, controls, metrics for reliability versus cost.

Frequency Risk and Control Report

The report sets out the assessment results of the operational frequency risks on the system. It includes an assessment of the magnitude, duration and likelihood of transient frequency deviations, forecast impact and the cost of securing the system. It confirms which risks will or will not be secured operationally by the ESO in line with the expectation set out under paragraphs 5.8, 5.11.2, 9.2 and 9.4.2 of the SQSS. The SQSS notes that the FRCR will set out those conditions under which unacceptable frequency conditions will not occur.

Following discussions with the SQSS panel and Ofgem, it was agreed that this edition of 2022 FRCR would combine both the report and methodology into a single consultation. This combined report and methodology considers the value proposition of securing against simultaneous events.

This combined report and methodology will be consulted on between 21 February and 4 March. The final report will be submitted to the Authority for approval on 01 April 2022.

3.2 What is the FRCR?

The FRCR sets out the results of an assessment of the operational frequency risks on the system which includes:

- the magnitude, duration and likelihood of transient frequency deviations,
- the forecast impact,
- the cost of securing the system,
- 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.

3.3 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 SQSS and the FRCR. 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.

3.4 Levels of impact

The report has used four levels of impact set out below when assessing the balance between the key objectives. These allow comparison with historic performance:

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

3.5 Metrics: 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, and/or
- Likely to occur, and/or
- Have a large impact.

Poor value risks are likely to be those which are:

- High cost to mitigate, and/or
- Unlikely to occur, and/or
- 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 FRCR assessment assesses 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.

3.6 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:

1. How often they occur,
2. How long they last for,
3. How large they are.

Each of these affects the impacts of an event (see section 3.4). For example: larger or longer deviations that happen very rarely might be acceptable, but smaller or shorter deviations that happen very often might not. The report will define what is considered reasonable as infrequent and tolerable for each of these criteria for transient frequency deviations.

3.7 What drives direct costs?

NGESO uses Ancillary Services to manage frequency deviations. Some are automatic, like frequency response. Others are manually dispatched, like reserve, the Balancing Mechanism (BM), services to increase the inertia or services to pre-emptively decrease the size of potential loss risks. In this document, we refer to these 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 2022.

3.8 How to balance between reliability and costs?

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.

4. Scope of this year's report

4.1 Performance of 2021 report

The implementation of FRCR 2021 was staged into two phases due to the significant impact on tools and processes. Phase 1 relaxed the normal infeed loss constraint (always securing a <=1000MW loss to 49.5Hz, and always securing infeed losses to the wider 49.2Hz limit) and recategorizing some loss risks which meant that no additional actions are taken to secure these risks. Phase 2 built from phase 1 and meant that we no longer secured loss risks based on Rate of Change of Frequency (RoCoF) if the total loss could be secured to 49.2Hz with the total response holding (including Dynamic Containment).

Following the implementation of Phase 1 of the FRCR recommendations in May 2021, the volumes of interventions that the ESO has been required to take in market dispatch through trades or BM actions has decreased significantly compared with previous years (see figure 1 below). The system wide response and inertia controls have meant that the ESO is required to take less direct action to manage inertia. In 2020, RoCoF curtailment actions (through both BM and trades) totalled 7.4TWh. This reduced to 2.3TWh in the first half of 2021 and 935GWh in the second half of 2021.

Figure 1 Reduction in ESO actions required to curtail RoCoF risks

This was possible because of the implementation of our frequency strategy, including Phase 1 and 2 of FRCR, a reduction in RoCoF and Vector Shift (VS) risk delivered through the ALoMCP, and the introduction of the fast-acting DC product.

In addition there was a reduction in the risk of LFDD events on the system following the implementation of the our frequency strategy, combining the impact of the Accelerated Loss of Mains Change Programme (ALoMCP), increasing Dynamic Containment (DC) volumes and the 2021 FRCR policy. This was part of the assessment and further information can be found in section 6.5 [3].

Since the policy updates implemented in FRCR 2021, there have been twelve occasions where the ESO secured events that were outside of the implemented policy. In these cases, perceived increased risk led to coverage of events that are not typically secured under current policy. Most of the exceptions were due to extreme weather conditions and the rest were due to the commissioning of new BMU(s).

[3] It should be noted that FRCR 2021 did not include simultaneous events in the system background risk profile whereas FRCR 2022 does. Appendix 9.4 compares the residual risk using the same background (without simultaneous events) as calculated in FRCR 2021.

4.2 Scope of the 2022 edition

The 2021 edition of FRCR considered one loss event at a time, as well as the combined loss of a BMU+DER (with Distributed Energy Resource (DER) loss occurring due to RoCoF or VS protection). Historically, the combined size of the largest infeed losses in the system have been too large to manage with conventional response and securing simultaneous events would often have been infeasible due to the design of the response products available.

Now new faster-acting frequency response products like DC offer the capability to secure larger losses (such as simultaneous losses).

The scope of the 2022 FRCR report investigates the feasibility and value to the end consumer of securing simultaneous losses. Simultaneous events are a complex area due to the large number of potential simultaneous events, the dependency between them and the large impact they may have on the system. The definition of simultaneous events used in this report set out in 5.1, as well as the assumptions made to simplify the analysis.

The methodology used sets out an objective and transparent framework for NGESO to assess risks associated with frequency deviations caused by simultaneous events. This includes types of simultaneous events which could cause large frequency deviations and investigates the range of simultaneous loss sizes, the impacts they have, whether they are feasible to secure or not and the cost and mix of controls to mitigate them. The assessment can then determine if securing simultaneous events results in a good balance between reliability and cost.

The ‘Future considerations’ section at the end of the report outlines opportunities to address other considerations in future editions to increase end consumer value.

4.3 Controls

There are four main controls for mitigating transient frequency deviations, set out below. However, under current system conditions, the only cost-effective action for managing simultaneous events is frequency response. The main controls are detailed below:

1. **Holding frequency response**: frequency response refers to NGESO holding of frequency services that are automatically activated by a frequency measurement to determine an appropriate change in active power. This injection of active power helps offset the impact of declining inertia. NGESO developed a fast-acting frequency response product, DC, that responds to a change in frequency in a timeframe of seconds.
2. **Reducing BMU loss size**: this control aims to reduce the output of the BMU such that if the unit faults and disconnects, it will not result in the frequency dropping below the threshold set by NGESO. Reducing BMU loss size to manage simultaneous events is not a credible option due to the number of BMUs in any given settlement period that could be paired to produce a relatively large simultaneous event. Targeted bids would have to be applied to numerous units as there is no way of knowing in advance which pair of units may trip which would lead to an over-constrained system.
3. **Reducing LoM loss size**: as a consequence of the ALoMCP, the capacity of DERs at risk of disconnection from the operation of Loss of Mains (LoM) relays has decreased significantly. This has an impact on the quantity of frequency response that needs to be procured. Reducing the LoM loss size makes minimal difference to the size of simultaneous event and hence is not a cost-effective way to manage simultaneous events.
4. **Increasing inertia**: the impact of increasing system inertia is a slowdown of frequency decline following a loss of generation. We can instruct units in the BM to increase their output, therefore increasing inertia on the system. However, increasing inertia is not a cost-effective method for securing simultaneous events as it would be infeasible to increase the minimum inertia sufficiently to manage simultaneous events due to the significant increase required.

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5. Methodology

The aim of the methodology is to set out an objective and transparent framework for NGESO to assess risks associated with frequency deviations caused by simultaneous events. This includes types of simultaneous events which could cause large frequency deviations and investigates the range of simultaneous loss sizes, the impacts they have, whether they are feasible to secure or not and the cost and mix of controls to mitigate them. The assessment can then determine if securing simultaneous events results in a good balance between reliability and cost.

5.1 Definition of simultaneous events

The table below sets out the criteria that define simultaneous events as well as the assumptions made to simplify the analysis.

Table 1: Definition of simultaneous events

Item	Explanation
Causal or coincidental events?	Modelling dependence between loss events is challenging due to the complex interactions within the system. Operational experience means that we know simultaneous events occur more frequently than mathematical probability suggests. This analysis focuses on the total cost of securing simultaneous events and infers how likely these events would need to happen to represent good value risks to secure in comparison to the BMU-only and BMU+VS event categories.
What events make a simultaneous event?	BMU-only events are considered as part of simultaneous events as they are more likely to occur than BMU+VS events and represent a greater degree of risk in the system. VS losses are not included in the overall simultaneous loss. Consequential RoCoF losses are included.
How close in time should events be?	The analysis focuses on a total loss made up of BMU-only events occurring at the same time instant as this represents the most onerous condition from a response perspective.
How many events should make up a simultaneous event?	The methodology considers two BMU-only events combining into a simultaneous event due to the computational complexity in investigating higher order events. We focus on total loss size combined from each pair of BMU losses including any consequential RoCoF losses.
Which pairs of events should make up simultaneous events?	The analysis focuses on a statistical view of the simultaneous event category including the median, upper 75% quantile and maximum total loss size per settlement period, due to the large number of possible simultaneous event combinations
Minimum BMU output	For each settlement period, we only consider BMU's generating/importing >= 100MW as this will include large interconnectors and exclude smaller units or units not connected that would skew the simultaneous loss statistics.
Infeed or outfeed losses?	There are many more infeed losses than outfeed losses so a high frequency simultaneous events is very unlikely and hence was not considered.

5.2 Methodology description

The analysis uses the same methodology set out in the previous edition of the FRCR[4] but adapted to incorporate simultaneous events. This can be summarised in the steps below:

1. Define scenario
2. Determine system-wide costs
3. Determine if targeted actions are required

[4] https://www.nationalgrideso.com/document/185856/download

4. Determine overall cost vs risk trade-off of the scenario

The remainder of this section explains the methodology steps in detail.

Step 1: Set-up scenario

Initially, all inputs are loaded into the model, including costs for response and targeted actions, LoM load factors and fault stats. Due to the significant change going on in the electricity industry, many of these key inputs can change year to year. Initially the model is based on a 2021 dataset, but corrected for these changes to represent 2022.

Baseline system conditions

The analysis uses historic scenarios adjusted for known or expected changes in the coming 12 months to isolate the reliability versus cost decisions from the impact of these wider changes. Example of adjustments include new connections to the National Electricity Transmission System (NETS) in 2022, which represent additional loss risks and which decrease the inertia of the system.

Many of the key inputs such as demand, inertia, BMU loss size, LoM loss size, vary markedly with time; hourly, daily, weekly and seasonally. Analysis of a single point in time, for example winter peak or summer minimum, would not capture the intricacies and interactions or give a true picture of risk exposure. This approach is used by some system operators in other countries but is inappropriate for assessing frequency risks on the GB system. This is due to the complexities of GB system operation where operational costs are driven year-round as opposed to a system peak/summer minimum. To overcome this, the analysis is performed as a time series at settlement period granularity.

These are the baseline system conditions against which the different control scenarios are assessed. NGESO will unwind balancing actions from the historic data sets to get a representation of the “market position” for these baseline system conditions.

Define scenario parameters

The analysis has taken the expected position for frequency response volumes for two scenarios: current FRCR policy and the additional actions required to secure simultaneous events. The LoM risks and minimum inertia policy (140GVAs) is assessed to determine the impact on the overall cost and baseline level of system risk. LoM capacity is forecast for 01 January 2022 onwards for both RoCoF and Vector Shift.

Step 2: Determine system wide costs

Frequency response (Primary, Secondary, High, DC and Enhanced Frequency Response (EFR)) and inertia costs are applied first as they affect all events and loss risks. Costs for inertia (including footroom) and BMU loss size are benchmarked against the typical prices achieved through the BM and trading.

The quantity of DC to be procured is calculated based on securing the maximum single BMU loss and any consequential RoCoF loss. This is a variation from last year’s methodology in which the estimated quantity of DC was an input variable. The quantity and price of the different frequency response services are benchmarked against the results of previous tenders or auctions.

Once the system-wide controls are in place, we calculate the expected loss size for the event, accounting for the BMU loss size and any consequential Vector Shift and / or RoCoF loss. Finally, we assess how often each event is at risk of causing each of the impacts before any individual loss risk controls are applied.

It should be recognised that the costs produced are based on the current system and market conditions and therefore are purely indicative. They are not forecast costs for 2022 and outturn costs might well change due to pricing, behaviour and forecast uncertainty etc.

Step 3: Determine if targeted actions are required

Initially the required reduction in the BMU loss size is calculated to prevent the event loss size exceeding the level of frequency response being held under the system-wide controls for each event considered and for each settlement period. This reduction could be:

- Preventing a consequential RoCoF loss from occurring, by making sure the total BMU / VS loss stays within the rate of change of frequency threshold, or
- Allowing a consequential RoCoF loss, but making sure the total BMU / VS / RoCoF loss stays within the level secured by frequency response holdings

The action selected is assumed to be the one with lowest MW reduction (and therefore cost). As explained previously, the main control for managing simultaneous events is to procure frequency response to cover the total loss and other options are not considered.

Step 4: Determine overall cost versus risk trade-offs of scenario

Determine costs of targeted actions

The cost for each targeted action is calculated for each event.

Calculate residual risk

Due to the physical constraints on BMUs, such as inflexible plant or other industrial processes, there may still be some periods which can't be mitigated by individual loss risk actions. A second assessment conducted, to evaluate how often each event is at risk of causing each of the impacts after both the system-wide and individual loss risk controls are applied. This is the residual risk.

Calculate risk reduction

The risk reduction achieved is calculated by applying the individual loss risk control and comparing the baseline risk (after system-wide controls) to the residual risk (after system-wide and individual loss risk controls).

Each event is ranked for risk reduction and the cost of applying the individual loss risk controls (in terms of the cost per avoided event), giving a “value for money” ranking. This allows the identification of a boundary between events which are good value to secure and those which are not good value to secure. The cost per avoided event is used at this boundary to determine the rate of occurrence of simultaneous events that would represent good value to secure.

6. Assessment and results

6.1 Input dataset

The assessment requires data to assess the cost versus risk of different scenarios. We have used historic scenarios adjusted for known or expected changes in 2022, as described in the methodology. The 2021 calendar year dataset has been used as the baseline for the report. The impact of new transmission connections and growth of embedded generation on system inertia has also been factored into the dataset used for the assessment.

6.2 FRCR 2021 policy

The starting point for the assessment is the 2021 Policy (see appendix 9.1). Current policy is based on allowing BMU-only infeed loss risks to cause a consequential RoCoF loss, only if the resulting loss can be contained to 49.2 Hz and 50.5 Hz. Minimum inertia is maintained at 140GVA.s. The policy also assesses the value in taking additional actions to apply individual loss risk controls to BMU+VS events and procuring enough response to fully secure simultaneous events.

6.3 Event categories

FRCR 2022 covers three categories of loss risks including:

- BMU-only
- BMU+VS
- Simultaneous events

BMU-only and BMU+VS risks were considered as part of FRCR 2021 which recommended applying individual loss risk controls to BMU-only risks to keep frequency deviations within 49.2Hz and 50.5Hz. No additional loss risk controls are applied to BMU+VS events. A detailed explanation of the different event categories can be found in the appendix.

Simultaneous events form a new category that are considered in this report and are defined in 5.1. There are approximately 4000 simultaneous events made up of each individual set of loss pairs. Each of these loss sizes would need to be calculated for each settlement period across the study year and processed by the FRCR model. Due to the computational complexity involved, a statistical summary of simultaneous event loss sizes has been used to determine the value in securing these events. The summary measures are each calculated per settlement period for the chosen study year. Consequential RoCoF losses were also included, and the total loss produced as a time-series for each of the following summary measures:

- Median simultaneous event loss size,
- Upper quantile simultaneous event loss size,
- Maximum simultaneous event loss size.

6.4 Application of controls within the methodology

Section 4.3 provides an overview of the main controls available to the ESO for managing transient frequency variations. We set out below how each of these controls have (or have not) been accounted for within the methodology of this report:

Control	How has this been applied in the methodology?
Holding frequency response	The expected position for frequency response volumes has been applied for (1) current FRCR policy and (2) the additional actions required to secure simultaneous events.
Reducing BMU loss size	Only BMU+VS considered.
Reducing LoM loss size	Control not applied within the methodology.
Meeting minimum inertia	Minimum inertia is maintained at 140GVAs as a static input.

In addition, Dynamic Moderation (DM) and Dynamic Regulation (DR) have not been considered in the methodology. This is due to the small volumes that will be procured after launch in Spring 2022 and the fact that they are pre fault services.

For Primary, Secondary and High (PSH) response, we have not optimised this service within the methodology, rather we have applied a set value of 550MW which is set for pre-fault reasons.

6.5 Security impact of the implementation of FRCR 2021

Assessing the impact of frequency policy before and after the implementation of FRCR 2021 shows the reduction in likelihood for a low frequency demand event. FRCR 2021 explicitly assessed the impact of allowing consequential RoCoF events to occur if the total loss (BMU loss + RoCoF loss) could be contained to within 49.2Hz (and restore frequency to above 49.5Hz within 60 seconds). Prior to the implementation of FRCR, the ESO would prevent a BMU-only or a BMU+RoCoF loss from causing a frequency deviation below 49.5Hz (for smaller infeed loss <= 1000MW) or 49.2Hz for larger infeed losses (>1000MW). This generally meant the ESO would not let BMU-only risks cause cause consequential RoCoF losses, by taking bids to reduce the infeed loss and resulting RoCoF to below 0.125Hz/s. As a result, the ESO would generally have held enough response to cover a maximum 1260MW loss.

Post-FRCR 2021, the ESO has held a greater volume of response to cover larger total infeed losses and reduce market intervention to manage these losses with targeted bids. The figure below compares both policies in terms of the coverage they provide for a range of loss sizes. All event categories include consequential RoCoF loss. The impact of this is two fold, it reduces the risk of a low frequency demand event and also increases the coverage of simultaneous events.

Reduction in risk of a low frequency demand event

Figure 2 shows how current policy of securing the total BMU + RoCoF loss, reduces the risk of an LFDD event. It should be noted that neither current FRCR or pre FRCR policies secure the maximum simultaneous loss event. In addition the coverage of simultaneous events has increased post the introduction of FRCR from covering 56% of all simultaneous events to 74% when securing to 49.2Hz.

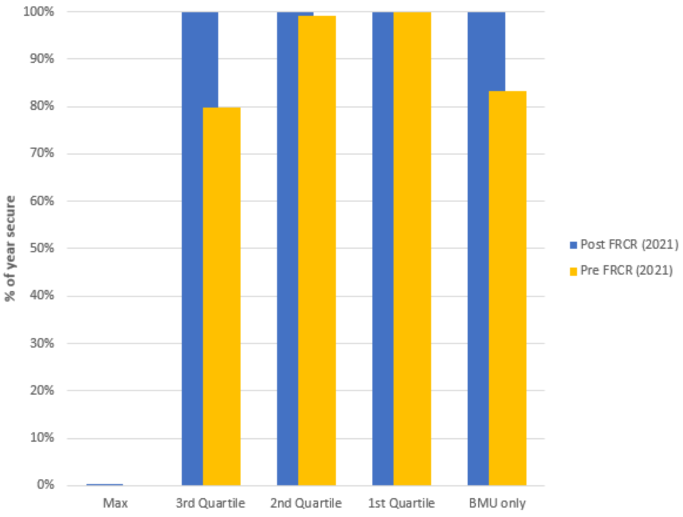

Figure 2 Comparison of current versus historic policy of the risk of an LFDD event

6.6 Assessment of current policy on 2022

The impact of the current FRCR policy (see appendix 9.1) on the risk profile for 2022 is set out below. Unlike last year, simultaneous events have been included in the overall system risk background. This means that the risk profiles calculated below are not comparable to the previous year[5].

Simultaneous event loss risks were added into the analysis of the overall system risk with the following assumed risk profile:

- 1-in-10-year risk of a median simultaneous event,
- 1-in-20-year risk of an upper quantile simultaneous event,
- 1-in-30-year risk of the peak simultaneous event.

This results in:

- £330M spend on frequency response controls to fully mitigate all BMU only infeed and outfeed loss risks, resulting in residual risk of a 49.2Hz event of 1-in-14 years and for 48.8Hz event of 1-in-28 years (based on existing policy). Note that the indicative cost of DC responses services is £190m of the £330M.
- An additional spend of £57M to manage BMU+VS (outage) events resulting in residual risk of 1-in-16 years and 1-in-30 years of a 49.2Hz and 48.8Hz events respectively.
- A further spend of £1.4B to manage BMU+VS (intact) events resulting in residual risk of 1-in-18 years and 1-in-30.5 years of a 49.2Hz and 48.8Hz events.
- 50.5Hz are unchanged as the report only considers infeed simultaneous loss risks.

This shows that the existing policy is still good value for the end consumer and the additional costs to secure BMU+VS are poor value. This aligns with the existing FRCR 2021 policy.

Going forward and to be included in future years FRCR, the delivery of the ALoMCP impacts the cost versus risk balance and will inform the value of continued delivery of RoCoF and Vector Shift relay changes through the ALoMCP and their resultant reduction of system risk in 2022. Response requirements are driven by both larger infeed losses and consequential RoCoF losses. A reduction in the RoCoF loss results in a corresponding reduction in response volumes and cost.

6.7 Assessment of securing simultaneous events

The additional cost of procuring response above current policy to secure all simultaneous events is £370M per year. Aligning the decision making around current FRCR policy against the additional cost to secure simultaneous events leads to a required rate of occurrence for simultaneous events to be of comparable value to the current cost versus risk boundary. Comparing the additional £370M per year spend on securing simultaneous events against the value ranking of the BMU+VS category (where no additional loss risk controls are applied) leads to a required occurrence rate of 1-in-2.5 years of an insecure simultaneous event. This does not align with our real-world experience of insecure simultaneous events where we have had 3 events in the last 30 years. Therefore, we do not consider the increased cost to represent good value for consumers.

[5] For comparison equivalent risk profiles for 2022 that do not include simultaneous events have been calculated and are included in appendix 9.4.

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7. Conclusions

7.1 Recommendation

The recommendation is to continue with existing policy. We do not believe it currently represents good value to secure for simultaneous events or take additional action to secure BMU+VS events. We therefore propose that policy remains unchanged and is set out in the bullets and table below. We will continue to keep the impacts of simultaneous events under review.

- 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 controls to BMU+VS events (intact or outage).
- Do not apply additional system-wide controls to secure simultaneous events.

	Event category			
	BMU-only	**VS-only**	**BMU+VS**	**Simultaneous events**
Considered by policy	Yes	Yes	Yes	**Yes**
Mitigated in real-time	Yes	n/a[6]	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	Frequency response
Additional control(s)	Inertia	Frequency response	n/a	Inertia Reduce LoM loss size

7.2 Consultation summary

The FRCR 2022 consultation was issued on the 21 February 2022, closed on 4 March 2022 and received four responses. A summary of the responses can be found in the table below, and the full responses can be found in on our website[7]. The key points from the consultation are detailed below:

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

[7] https://www.nationalgrideso.com/industry-information/codes/security-and-quality-supply-standards/frequency-risk-control-report

#	Question	Response summary
1	Overall, do you agree that the FRCR represents appropriate development in determining the way that the ESO will balance cost and risk in maintaining security of supply while operating the system?	Three respondents agreed with the overall assessment process, with one stating "probably", acknowledging this is a complex area and suggesting there may be merit in demonstrating how the summary results presented are derived.
2	Do you agree that the FRCR has been prepared appropriately?	Three respondents agreed with the overall approach, with one respondent providing a general, high level position of agreement with the approach across all questions. Another respondent noted that whilst they agreed with the overall approach, they did not necessarily agree with all conclusions.
3	*To help structure comments, do you agree with and what is your feedback on the specific recommendation in the FRCR?*	
4	**Recommendation**: **Simultaneous events** Continue with the current ESO FRCR 2021 policy and take no further actions to secure additional simultaneous events.	All four respondents agreed with the proposal. Two respondents provided further considerations, including a suggestion that BMU+VS events should be considered and disagreed with the statement that BMU+VS events are 1 in 30-year frequency. The other respondent agreed that covering all simultaneous events would not be cost effective but questioned where the optimal coverage level would be.
5	Do you have any suggestions for further areas that can be addressed in future editions of the FRCR	Two respondents provided no further comments. The other two provided suggestions on considering the length of LFDD events and not just the frequency with which they might occur. It was also suggested that the ESO should consider the impact of smaller frequency deviations on power quality.
6	Do you have any other comments?	Three respondents provided no further comments, with one providing specific amends on the report.

7.3 Implementation

As the recommendation is to continue with existing policy and not to secure for simultaneous events, there is no change to system operation and hence there is no implementation required.

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8. Future considerations

There are various 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. Such examples are described in the following section.

8.1 Events and loss risks

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: Future connections to the NETS, 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.

8.2 Impacts

Multiple stages of LFDD: Exploring whether events could cause more than one stage of LFDD, and how often this could happen. This would include the duration of LFDD events and the time taken to recover.

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[8] impact users, and how often they should be allowed to occur.

8.3 Controls

Response and Reserve: Future services developed under the Response and Reserve roadmap.

Inertia: Future stages of the Stability Pathfinder and new market mechanisms for accessing inertia and reducing the level of minimum inertia below 140GVA.s.

ALoMCP delivery: Cost and risk reduction achievable through full delivery of the programme.

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

8.4 Metrics

Other approaches to valuing cost versus 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.

8.5 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.

9. Appendices

9.1 Appendix 1: FRCR April 2021 policy

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[9]

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

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[10]

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.

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.

Reduce BMU loss size

NGESO will;

a) Infeed loss risks

Allow BMU-only infeed loss risks to cause a consequential RoCoF loss where the resulting loss can be contained to 49.2Hz. If the resulting loss cannot be contained to 49.2Hz, then take bids to reduce the BMU-only infeed loss to prevent a frequency deviation below 49.2Hz, either by preventing the consequential RoCoF loss or reducing the overall BMU+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[11]

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[9] these are a loss of power outfeed and are typically smaller than 560MW

[10] for some loss risks, the inertia lost with the event means the threshold is slightly below 700MW

[11] 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

- 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

Variations to this policy

There are specific, limited variations to these policies based on technical, probabilistic and economic grounds, applied under paragraphs 5.11.2 and 9.4.2 of the SQSS. This includes additional actions where appropriate during times of increased system risk, such as during severe weather, and exceptions where risks cannot feasibly occur[12].

The FRCR is an assessment of all events across 2022, 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.

If and when this occurs, and as appropriate, the ESO will inform the Authority of such actions after they have been taken, and report relevant details in the following FRCR process.

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

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9.2 Appendix 2: Events and loss risks

BMU-only	An event which only disconnects one or more BMUs i.e., no Vector Shift (VS) loss or Rate of Change of Frequency (RoCoF) loss. These are caused by faults inside a particular BMU, or particular group of BMUs, which cause the associated infeed or outfeed to be disconnected from the transmission system, and do not cause an electrical disturbance which propagates into the distribution networks, causing a consequential VS loss. Without any containment or mitigation controls, transient frequency deviations following these events would be very common.
VS-only	An event which causes a consequential VS loss with no BMU loss or RoCoF loss. These are caused by faults on the National Electricity Transmission System which cause an electrical disturbance which propagates into the distribution networks, causing a consequential VS loss, and do not disconnect a particular BMU or group of BMUs from the transmission system. Without any containment or mitigation controls, transient frequency deviations following these events would be common.
BMU + VS	An event which only disconnects one or more BMUs and causes a consequential VS loss (no RoCoF loss). These are caused by faults on the National Electricity Transmission System which cause an electrical disturbance which propagates into the distribution networks, causing a consequential VS loss, and do disconnect a specific BMU or group of BMUs from the system due to the design of the network, for example a busbar fault, a generator transformer fault or a double circuit fault where it is the only connection to the network. Without any containment or mitigation controls, transient frequency deviations following these events would be rare.
BMU + RoCoF	A BMU loss which also causes a consequential RoCoF loss (no VS loss). Without any containment or mitigation controls transient frequency deviations following these events would be very common.
VS + RoCoF	A VS loss which also causes a consequential RoCoF loss (no BMU loss). Without any containment or mitigation controls, transient frequency deviations following these events would be common.
BMU + VS + RoCoF	a BMU + VS loss which also causes a consequential RoCoF loss. Without any containment or mitigation controls, transient frequency deviations following these events would be rare.

9.3 Appendix 3: SQSS glossary

All the terms and definitions contained in this report have the meaning as set out in the National Electricity Transmission System Security and Quality of Supply Standard. To aid the reader, these definitions are reproduced below:

Authority	This means the Gas and Electricity Markets Authority established by section 1(1) of the Utilities Act 2000.
Frequency Risk and Control Report	The periodic report setting out the results of an assessment of the operational frequency risks on the system produced by NGESO and approved by the Authority and as set out in the SQSS Appendix H, and prepared in accordance with the Frequency Risk and Control Report Methodology as also prepared and approved as set out in the SQSS Appendix H. The report shall include an assessment of the magnitude, duration and likelihood of transient frequency deviations, forecast impact and the cost of securing the system and confirm which risks will or will not be secured operationally by NGESO in accordance with paragraphs 5.8, 5.11.2, 9.2 and 9.4.2.
Frequency Risk and Control Report Methodology	The methodology by which a Frequency Risk Control report will be developed, consulted on and approved by the Authority, and as set out in the SQSS Appendix H.
Loss of Power Outfeed	The output of a generating unit or a group of generating units or the import from external systems disconnected from the national electricity transmission system by a secured event, less the demand disconnected from the national electricity transmission system by the same secured event. For the avoidance of doubt if, following such a secured event, demand associated with the normal operation of the affected generating unit or generating units is automatically transferred to a supply point which is not disconnected from the system, e.g. the station board, then this shall not be deducted from the total loss of power infeed to the system. For the purpose of the operational criteria: i) the loss of power infeed includes the output of a single generating unit, CCGT Module, boiler, nuclear reactor or import from an external system via a HVDC Link. **ii)** In the case of an offshore generating unit or group of offshore generating units, the loss of power infeed is measured at the interface point, or user system interface point, as appropriate. **iii)** In the case of an offshore generating unit or group of offshore generating units for which infeed will be automatically re-distributed to one or more interface points or user system interface points through one or more interlinks, the re-distribution should be taken into account in determining the total generation capacity that is disconnected. However, in assessing this re-distribution, consequential losses of infeed that might occur in the re-distribution timescales due to wider generation instability or tripping, including losses at distribution voltage levels, should be taken into account.

9.4 Appendix 4: Assessment of current policy on 2022 (without including simultaneous events)

FRCR 2021 did not include simultaneous events in the overall system risk background. This means that the risk profiles calculated for 2022 are not comparable to the previous year. For comparison with last year, the 2022 risk profiles without including simultaneous events are set out below**. Note the reduction in system risk compared with FRCR 2021 if simultaneous events are not included in the overall system risk background.**

Current policy is based on overall system risk derived from BMU only and BMU+VS events. Based on this, the indicative costs to secure these events and the residual risk is:

- £330M spend on frequency response controls to fully mitigate all BMU only infeed and outfeed loss risks, resulting in residual risk of a 49.2Hz event of 1-in-50 years and for 48.8Hz event of 1-in-950 years. The residual risk of a 50.5Hz event is 1-in-1500 years.
- An additional spend of £57M to manage BMU+VS (outage) events resulting in residual risk of 1-in-100 years and 1-in-2000 years of a 49.2Hz and 48.8Hz events and a 1-in-2000-year risk of a 50.5Hz event.
- A further spend of £1.4B to manage BMU+VS (intact) events resulting in residual risk of 1-in-3000 years and 1-in-10000 years of a 49.2Hz and 48.8Hz events and a 1-in-10000-year risk of a 50.5Hz event.