NG ESO and WPD

OPTIMAL COORDINATION OF ACTIVE NETWORK MANAGEMENT SCHEMES WITH BALANCING SERVICES MARKETS

Report on workstream three: identification of solutions

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EXECUTIVE SUMMARY

Active Network Management (ANM) schemes are becoming increasingly widespread on GB distribution networks, alongside the development of some ANM schemes on the transmission network. The schemes vary in complexity and scale, but to date all have a similar purpose: to enable generation to connect to the transmission or distribution networks more quickly and at lower cost by actively managing their power output to avoid breaching existing network limits, rather than undertaking network reinforcement. ANM schemes benefit consumers by minimising the costs of connecting new low carbon generation, which helps to decarbonise the network and reduce costs to consumers.

At the same time as ANM scheme use is increasing, National Grid Electricity System Operator (NG ESO) is increasingly using distributed assets for the provision of Balancing Services (including the Balancing Mechanism, response and reserve services). This benefits consumers by increasing market liquidity and ultimately reducing costs.

But risks arise in instances where NG ESO procures Balancing Services from distributed assets that are behind network constraints managed by ANM schemes, as discussed at length in the previous project report[1]. This project is seeking to optimise coordination between ANM systems and NG ESO's operation of Balancing Services. This report represents the conclusion of the third workstream, through which we have identified a range of solutions to the coordination issues presented in the first report.

The solutions considered fall into four main groups:

- Reconfiguration of ANM schemes
- Improved information exchanges and coordination of schemes
- Changes to market rules
- Coordination between CLASS and ANM schemes

In reality, the optimal outcome is likely to incorporate a combination of solutions from each of the above groups to reach a well-coordinated outcome in which all parties have access to the information they require to make informed decisions.

From a high-level assessment of the solutions considered, five have been identified as having the most potential, namely (in no particular order):

[1] https://www.westernpower.co.uk/downloads-view/164437

- Parallel instructions from NG ESO to DER and ANM schemes in which NG ESO instructs a decrementing service, resulting in the ANM holding headroom to avoid counteracting the service requested by NG ESO;
- Preparatory instructions from NG ESO to ANM for delivery of Frequency Response, requiring the ANM scheme to hold headroom to enable the frequency response service to be delivered;
- Improved communication with generators on the likelihood of ANM curtailment in a given Settlement Period;
- Risk-based Balancing Services valuation by NG ESO based on the likelihood of ANM curtailment in each Settlement Period; and
- Improved visibility between Balancing Services schemes such as CLASS and ANM, with DNOs to coordinate CLASS and ANM ahead of the event to ensure the agreed amount of services can be provided to NG ESO.

These solutions address different issues, with some solutions overlapping in the risks they address.

The next stage of this project will involve a thorough cost-benefit analysis of these proposed solutions followed by the development of a detailed delivery plan for the deployment of the optimal solution(s).

1 PROJECT OVERVIEW

WSP[2], Cornwall Insight[3] and Complete Strategy[4] are undertaking a Network Innovation Allowance (NIA) funded project on behalf of National Grid Electricity System Operator[5] (NG ESO) and Western Power Distribution[6] (WPD). The project is investigating the optimal coordination of Active Network Management (ANM) schemes on both the distribution and transmission networks with Balancing Services markets.

1.1 BACKGROUND

NG ESO's Future Energy Scenarios[7] (FES) and System Operability Framework[8] (SOF) show that the installed capacity of Distributed Generation (DG) has increased to 31GW in 2018 and is set to rise to a level of 38 – 69GW by 2030 across all FES scenarios. This significant growth of DG, together with the development and adoption of smart grid technologies, means that network operators, both transmission and distribution, have the need and the means to more actively manage flows on their networks.

DG often connects in clusters on the distribution network, in many cases due to natural resources and land availability (e.g. high concentrations of solar in the South West and high concentrations of wind in Scotland). As a result, it has the potential to breach operational limits on both the local distribution network where it is connected but also on the upstream transmission network in that area.

1.1.1 INCREASED USE OF ANM

Distribution Network Operators (DNOs) have introduced ANM schemes to manage generation and demand dynamically and in real time in order to:

- Increase the utilisation of network assets without breaching operational limits;
- Reduce the need for connection-related reinforcement; and
- Speed up connection timelines and reduce connection costs.

There is an increasing number of constraints on DNO networks that are likely to be managed by ANM systems over the next five years, demonstrated by the extent of planned distribution ANM schemes which the DNOs are considering. ANM schemes on the distribution network are also increasingly being used to manage transmission constraints by monitoring and controlling power flows at the transmission to distribution interface (i.e. the supergrid transformers at Grid Supply Points).

[2] https://www.wsp.com/en-GB
[3] https://www.cornwall-insight.com/
[4] https://complete-strategy.com/
[5] https://www.nationalgrideso.com/
[6] https://www.westernpower.co.uk/
[7] http://fes.nationalgrid.com/
[8] https://www.nationalgrideso.com/insights/system-operability-framework-sof

Similarly, the Network Options Assessment[9] (NOA) identifies increasing constraint issues on the transmission system, driving Transmission Owners (TOs) and NG ESO to propose and develop the use of ANM on the transmission system to optimise power flows at constraint boundaries, although these systems are not yet in operation.

1.1.2 INCREASED USE OF DISTRIBUTED ASSETS FOR BALANCING SERVICES

Meanwhile, NG ESO is increasingly instructing flexible demand and generation connected to the distribution network, both through procurement of Balancing Services[10] ahead of time, such as Firm Frequency Response (FFR) or Short-term Operating Reserve (STOR) and closer to real time services through the Balancing Mechanism (BM) Wider Access programme and the ongoing implementation of Project TERRE.

Markets for Balancing Services are also evolving as deployment of subsidy-free renewables connected to the transmission system develops. Subsidy-free generators are more likely to provide services to NG ESO through, for example, the Balancing Mechanism than their subsidised equivalents as they are more cost effective for NG ESO to deploy. Such generators are also likely to cluster, with South Scotland being an area of particular interest.

1.1.3 RISK OF CONFLICTS

As a result, there is increasing potential for the actions of ANM schemes to interact with Balancing Services procurement. Without coordination of activities between NG ESO and DNOs, there is potential for:

- ANM schemes to counteract actions instructed under NG ESO's Balancing Services or to cancel out the effect of Balancing Services procured from Distributed Energy Resources (DER); and
- DER connected to ANM arrangements to be unnecessarily blocked from participation in Balancing Services.

The ultimate goal of this project is to determine approaches to optimal coordination of ANM with Balancing Services, to address the project's core problem statement:

ANM schemes which are not coordinated with wider Balancing Services markets will increase costs to consumers and may pose a risk to security of supply.

1.1.4 BROADER CONTEXT

More broadly, as network operators (most notably DNOs) start taking a more active role in managing flows on their networks, greater collaboration and coordination with NG ESO is required to efficiently manage the whole system.

[9] https://www.nationalgrideso.com/document/162356/download
[10] For simplicity and consistency any action taken by NG ESO will be referred to as "Balancing Services" in this document.

For example, the Future Worlds[11] developed under the Open Networks Programme[12] considered different approaches to the coordination of procurement of flexibility services from DERs by both the future Distribution System Operator (DSO) and NG ESO.

We expect that our findings on specific coordination issues between ANM and Balancing Services may be applicable in this broader context, which we will consider towards the end of the project.

1.2 PROJECT STRUCTURE

The project is composed of six Workstreams (WS) with individual objectives and associated deliverables. The six WSs of the project are broadly described as follows:

- **Workstream 1**: Identify and review current ANM schemes, their associated technical and commercial arrangements, the risks which arise if ANM systems are uncoordinated with Balancing Services, and any coordination already in place.
- **Workstream 2**: Development of Test Cases against which the issues can be assessed, and a high-level assessment of potential benefits.
- **Workstream 3**: Identification and definition of solutions to optimise coordination of ANM schemes with Balancing Services based on the Test Cases identified under WS2.
- **Workstream 4**: Cost benefit analysis of the network Test Cases and potential solutions.
- **Workstream 5**: Delivery plan for practical deployment of optimal feasible solutions as determined under WS4, covering changes that would need to be made to the existing technical, commercial and market arrangements.
- **Workstream 6**: Dissemination of findings and consideration of how those findings could be applied more widely to the simultaneous deployment of system services from DER by both DNOs and NG ESO.

The structure and associated stage gates are shown in Figure 1-1.

[11] https://www.energynetworks.org/electricity/futures/open-networks-project/workstream-products-2020/ws3-dso-transition/future-worlds/future-worlds-consultation.html
[12] https://www.energynetworks.org/electricity/futures/open-networks-project/open-networks-project-overview/

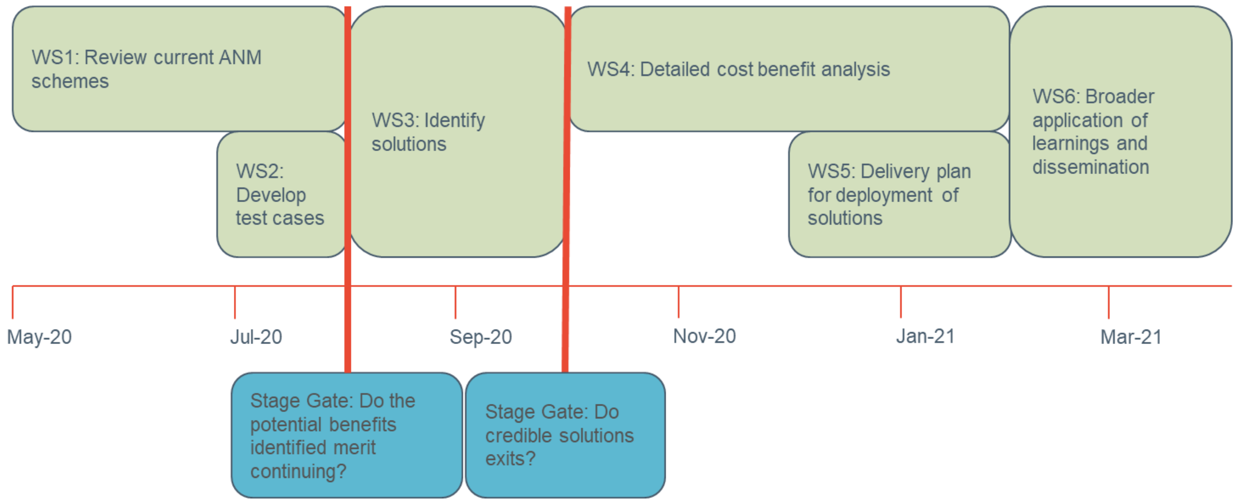

Figure 1-1: Project outline

1.3 PURPOSE OF THIS REPORT

This report concludes the second phase of the project and covers the findings of WS3 as shown in Figure 1-2.

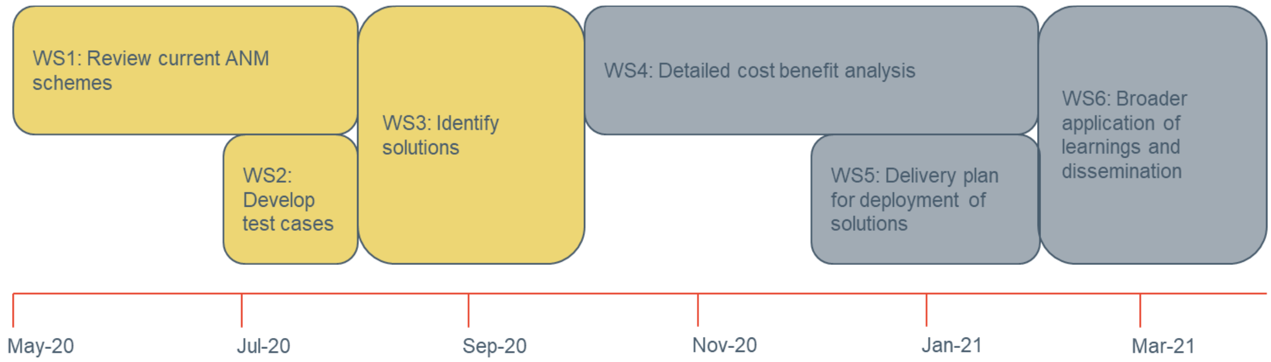

Figure 1-2: Focus of this report

It focuses on:

- A reminder of key terminology and the Test Cases as defined in the previous report (Section 2);
- Background to the proposed solutions presented (Section 3); and
- Detail on each proposed solution, a high-level assessment of its merits, and conclusions on next steps for each proposed solution (Section 4).

2 TERMINOLOGY AND TEST CASES

This section summarises key aspects of the WS1 and WS2 report, to aid understanding of this report. Further detail is included in the WS1 and WS2 report[13].

2.1 TERMINOLOGY

Distribution Active Network Management (ANM): Dynamic management of Distributed Energy Resources behind constraints to optimise utilisation of network assets without breaching operational limits, primarily to reduce the need for reinforcement driven by new connections, speed up associated connection times and reduce connection costs.

Last In First Off (LIFO) Stack: The order in which generators are typically curtailed on ANM systems, starting with those which connected most recently.

Generation Export Management Systems (GEMS): The use of ANM on the transmission network.

Generator with standard connection: This refers to generation connected in an area of the network where no ANM schemes are in place.

Non-curtailable generator in an ANM area: This refers to generation which is behind a constraint being managed by an ANM scheme but is not itself controlled by that ANM system. This may be because the generation in question connected before that ANM scheme was put in place and so does not sit in the LIFO stack, or that the generator is below that DNO's size threshold for inclusion on an ANM scheme.

ANM generator: Generator which is subject to curtailment by an ANM system.

GEMS generator: Generator which is subject to curtailment by GEMS.

2.2 TEST CASES

Table 2-1 summaries the Test Cases, which are set out in detail in the WS1 and WS2 report.

13 https://www.westernpower.co.uk/downloads-view/164437

Table 2-1: Summary of Test Cases

Test Case	Type of Test Case	Description
1A	ANM system counteracts Balancing Services provided by DER or transmission connected resources	Incrementing service action from a non-curtailable generator in an ANM area is counteracted by an ANM generator
1B		Decrementing service action from a non-curtailable generator in an ANM area is counteracted by an ANM generator
1C		Service action from a non-curtailable generator in a GEMS area is counteracted by a GEMS generator
2A	ANM system counteracts Balancing Services provided by DNO using CLASS system	Demand reduction through a lowering of tap position (through CLASS) is counteracted by downstream ANM scheme
2B		Demand boost through a raising of tap position (through CLASS) is counteracted by downstream ANM scheme
2C		Reactive power absorption through tap stagger (through CLASS) is counteracted by downstream ANM scheme
2D		Demand reduction through disconnection of one transformer is counteracted by downstream ANM scheme
3A	Non-delivery or non-participation by DER in Balancing Services due to ANM risks	ANM generator curtailed and defaults on Balancing Service
3B		ANM generator unable to access Balancing Services markets

3 BACKGROUND TO SOLUTIONS

3.1 DEVELOPMENT OF SOLUTIONS

In developing proposed solutions, we have sought a broad range of options to resolve the issues identified in the Test Cases described in the joint WS1 and WS2 report. These solutions have been developed and discussed with various stakeholders, through bilateral engagement and a workshop with the project Advisory Group.

With such a broad range of possible solutions in place, some initially look more credible than others. In this report, we have explored the high-level impacts on relevant parties (namely NG ESO, DNOs and generators) and considered the possible impact on cost to consumers. As a result, we have been able to rule out the least promising solutions and identify a subset which we will take forward for more detailed consideration.

3.2 SOLUTIONS OVERVIEW

The solutions we have proposed broadly fall into four categories:

- Reconfiguration of ANM schemes (solutions W1-W3)
  - These solutions focus on modifying the design, where necessary, of existing and new ANM schemes to either allow for NG ESO instructions to the ANM scheme, or alignment of ANM curtailment timescales with Balancing Services timescales.
- Improved information exchanges and coordination (solution X1)
  - This focuses on improving communication between ANM schemes and ANM generators, allowing generators to take informed decisions which avoid the issues identified in the Test Cases.
- Changes to market rules (solutions Y1 and Y2)
  - These solutions look to market-based remedies, either by accounting for non-delivery risk due to ANM in the processes used for procurement of Balancing Services, or broader changes to implement a market-based framework for allocating network capacity.
- Coordination with CLASS systems (solutions Z1 and Z2)
  - These solutions focus on aligning information between ANM and CLASS schemes, coordination of actions to avoid conflicts and apportioning compensation where necessary.

In reality, the optimal outcome could be any combination of the solutions we have identified. At this stage, however, we retain distinct solutions to be clear in terms of which of the issues identified through the Test Cases are being addressed by each solution.

4 SOLUTIONS LONGLIST

This section sets out the range of solutions in detail, covering the design of each solution, which Test Cases it relates to, and the impact on each of the key parties involved. It also sets out a high-level assessment of the pros and cons of each solution, and a recommendation on whether the solutions should be investigated in greater detail through a full cost/benefit analysis (CBA).

4.1 SUMMARY OF SOLUTIONS

As noted, a wide range of solutions have been identified, affecting different parties in different ways through their design. Table 4-1 groups together and summarises the solutions, including their high-level impacts on NG ESO, the DNOs and generators (both non-curtailable generators in ANM areas and ANM generators). Many of the impacts on generators would be similar to those for demand side assets, but impacts here are focused on generators given the vast majority of assets subject to ANM curtailment are generators.

The remainder of this section addresses each solution in turn.

Table 4-1: Summary of Solutions to Test Cases

Solution Category	Solution	Effect on Parties and Operational Impacts
W – Reconfiguration of ANM schemes	W1 – Parallel decrementing instruction to DER and ANM	NG ESO – coordinator, medium-high impact DNOs – reconfiguration, medium impact Generators – better access to Balancing Services, low impact
	W2 – Preparatory incrementing instruction to ANM	NG ESO – coordinator, medium-high impact DNOs – reconfiguration, medium impact Generators – better access to Balancing Services but increased curtailment for some, medium impact
	W3 – Bring ANM curtailment ahead of Gate Closure	NG ESO – additional parameters in BM dispatch, medium impact DNOs – ANM redesign and forecasting, very high impact Generators – better BM access but increased curtailment for some, medium impact
X – Improved information exchange	X1 – Improved communication with generators	NG ESO – update terms of Balancing Services, low impact DNOs – improved communications and continual forecasting, high impact Generators – much greater operational information, high impact

Y – Changes to market rules	Y1 – Risk-based Balancing Services valuation	NG ESO – coordinator of new framework, very high impact DNOs – forecasting and better ESO comms, high impact Generators – better access to Balancing Services, low impact
	Y2 – Framework for allocating network capacity	NG ESO – modify Balancing Services terms, low impact DNOs – design and implement framework, very high impact Generators – participation in market, high impact
Z – CLASS solutions	Z1 – CLASS to ANM coordination	NG ESO – status quo, low impact DNOs – coordinator (if using CLASS in load dominated areas), high impact Generators – status quo, low impact
	Z2 – CLASS visibility of ANM	NG ESO – status quo, low impact DNOs – coordinator (if using CLASS in load dominated areas), high impact Generators – status quo, low impact

4.2 DETAILED SOLUTION DESCRIPTION

This section sets out, for each solution:

- A detailed description;
- The impact on each of NG ESO, the DNOs and generators;
- Changes required throughout the industry or by individual parties to implement the solution;
- Pros and cons of the solution; and
- A recommendation on whether this solution should be explored in greater detail.

An additional section explores the implications for compensating generators for curtailment under these solutions.

4.2.1 SOLUTION W1: PARALLEL DECREMENTING INSTRUCTION TO DER AND ANM

4.2.1.1 Description

This is a solution to Test Case 1B (counteraction of decrementing service by ANM). That Test Case sees a decrementing service instructed by NG ESO from a non-curtailable generator in an ANM area counteracted by an ANM scheme releasing curtailment on an ANM generator in response to the headroom created. This could also apply to an ANM generator providing a decrementing service instructed by NG ESO, where that service provision is counteracted by the ANM scheme releasing curtailment on another ANM generator.

The solution would see a signal sent simultaneously to the generator and to the ANM scheme, requiring that the ANM scheme either:

- Holds headroom equivalent to the level of the decrementing service for the duration that the NG ESO service is required; or
- Does not release any existing curtailment for the duration that the NG ESO service is required.

This could be done through NG ESO having knowledge of which generators are subject to curtailment by ANM schemes, and issuing parallel instructions accordingly, or by NG ESO issuing instructions to the generator and DNO simultaneously, and allowing the DNO to manage the instruction to the ANM scheme.

While this is a relatively simple solution for situations where an ANM scheme is managing a simple constraint, it becomes more complex when generators have variable impacts on a constraint. As such, a 'sensitivity factor', taking account of the contribution a generator has to a given constraint, may need to be applied. A detailed analysis would be required to assess the implementation of this on complex networks. NG ESO issuing instructions to the DNO rather than directly to the ANM scheme would mitigate some of this complexity, as the DNOs will have a better idea of the parameters affecting sensitivity factors. However, this additional communication may increase the response time of the service provision. This should be factored into a detailed CBA of this solution.

4.2.1.2 Impact on Parties and Changes Required

NG ESO: Under this solution NG ESO would be required to issue instructions to ANM schemes alongside every decrementing instruction that involves a non-curtailable generator in an ANM area. This involves direct communication channels between NG ESO and DNO control rooms or directly with ANM schemes, depending on the links between DNO control rooms and ANM schemes on their networks. If NG ESO was to directly communicate with ANM schemes, it would also require knowledge of which generators are behind which ANM constraints, and the impact, or sensitivity factor, that should be applied to each generator in respect of each constraint.

DNOs: DNOs would be required to reconfigure ANM systems to allow for the holding of headroom when instructed by NG ESO. This should be relatively simple to incorporate into new schemes but may be more costly when retrofitting existing schemes. Engagement with ANM system providers is required to establish a more detailed view on costs. As noted above, it would also require better communications between DNO and NG ESO to allow these instructions to be made.

Generators: No structural changes would be required from generators. However, non-curtailable generators in ANM areas may have better access to Balancing Services markets, as delivery of decrementing services will not be counteracted. ANM generators would likely see marginally more curtailment under this regime, as headroom would not be released by the ANM during the provision of a decrementing service by another generator. This would not take generators beyond their expected curtailment (which is often provided to generators by DNOs), as the DNOs would not have forecast for the decrementing service and as a result the headroom would not have been expected to be available.

4.2.1.3 Pros and Cons

Pros:

- This solution fully avoids decrementing services being counteracted.

Cons:

- The solution is relatively limited in its scope, in that it is only viable for decrementing services (e.g. BM Bid Acceptance).
- ANM systems are curtailing marginally more than is necessary by holding headroom, restricting the efficiency of the ANM scheme. This should be factored into a CBA, but with care not to overstate the impact as the headroom which is held only exists as a direct result of the Balancing Service being instructed.

4.2.1.4 Recommendation

Implementation of this solution would rely on relatively modest improvements to information exchange in order for NG ESO to understand the location and sensitivity of each BMU to each ANM constraint, and for ANM systems to receive information from NG ESO relating to the dispatch of decrementing services downstream of the constraint. It should therefore be relatively straightforward to implement. It has the potential to deliver immediate benefits by removing counteraction risk, albeit that risk will only be removed for a subset of NG ESO services (namely those which decrement).

We propose to carry out a CBA on this solution to fully understand its merits and any implementation challenges.

4.2.2 SOLUTION W2: PREPARATORY INCREMENTING INSTRUCTION TO ANM

4.2.2.1 Description

This is a solution to Test Case 1A (counteraction of incrementing service by ANM). That Test Case sees an incrementing service instructed by NG ESO from a non-curtailable generator in an ANM area counteracted by an ANM scheme curtailing an ANM generator in response.

The solution proposes that, prior to each settlement period, NG ESO sends a signal to each relevant ANM scheme to provide the volume of potential incrementing services behind the constraint in that period (e.g. the volume of BM Offers). The ANM would then hold that level of headroom to enable those increments to be delivered without counteraction if called.

As is the case for solution W1, this is a relatively simple solution where the nature of the ANM system and the constraint is relatively simple. However, with more complex constraints and systems, with generators having variable impacts on constraints, the solution would become more complex. This would involve an assessment of sensitivity factors again, with different capacities to be held depending on the exact location and sensitivity factor of the generator providing the NG ESO service.

4.2.2.2 Impact on Parties and Changes Required

NG ESO: Under this solution, like solution W1, NG ESO would require the same communications infrastructure (NG ESO to DNO control room). If interacting with ANM systems directly, it would also need knowledge of generators in respect to ANM constraints, including sensitivity factors. However, this could be left to DNOs to implement, with the instruction given to the DNO control room. This would likely be an easier solution for more complex constraints and systems.

DNOs: Again, like solution W1, the main impact is on reconfiguring ANM systems to hold headroom as instructed by NG ESO, with costs likely determined by the current design of systems, but engagement with system providers needed to verify this. The DNOs would also need to maintain communications channels with NG ESO.

Generators: Some generators may be able to access Balancing Services that otherwise would have excluded them on the grounds of being behind an ANM constraint. However, ANM generators in an area where Balancing Services are procured will see increases in the level and frequency of curtailment, as the ANM seeks to maintain the required headroom for incrementing NG ESO services that could be called. This curtailment would be substantially more than curtailment under solution W1, as it is a bigger change to the operation of ANM systems.

4.2.2.3 Pros and Cons

Pros:

- This solution fully avoids incrementing services instructed by NG ESO being counteracted if the generator is behind an ANM constraint.

Cons:

- The efficiency of ANM schemes is restricted, as on aggregate large amounts of headroom may be held for incrementing services that are offered but may not be called.
  - This may work better for short term services such as frequency response, where the amount of headroom is relatively small and timeframes are shorter, compared to a service such as STOR where availability windows are long, and dispatch is in response to unpredictable events.
- Contractual terms between DNOs and generators may need to be reviewed as there are substantive changes to the operating regime of ANM systems under this solution. The contractual ability for DNOs to amend ANM operations in this way will depend on existing contractual terms and may vary by DNO.

4.2.2.4 Recommendation

As with solution W1, this solution should be relatively straightforward to implement. But there is an immediate issue with this solution that the ANM system is creating headroom in order for incrementing services to be delivered. As a result, for services such as the BM, it is unlikely to be a cost effective solution – the incrementing service which NG ESO is requesting may only need to be dispatched because the ANM reduced output from another generator in order to create the headroom for that service to be delivered. This does not present a good outcome for consumers, as there is a high likelihood of (low marginal cost) renewable generators being curtailed in order to create headroom for other, potentially higher marginal cost and non-renewable generators, to be dispatched under (e.g.) the BM in their place. However, there may be some merit in this solution for NG ESO services which require fast acting generation, such as frequency response.

We intend to carry out a CBA on this solution for frequency response only, where it may also be coupled with changes to market rules.

4.2.3 SOLUTION W3: BRING FORWARD ANM CURTAILMENT AHEAD OF GATE CLOSURE

4.2.3.1 Description

This is a solution relating to the BM, for the issues raised in Test Cases 1A (counteraction of incrementing service by ANM), 1B (counteraction of decrementing service by ANM), 3A (generator defaults on Balancing Service due to constraints) and 3B (generators with ANM connection prevented from accessing Balancing Services markets).

This solution would require DNOs to determine the level of ANM curtailment required for each Settlement Period at a pre-determined point in time ahead of that Settlement Period. Generators would then be able to submit Bids and Offers, and NG ESO would be able to dispatch with certainty on ANM curtailment, avoiding non-delivery and counteraction risk.

The optimal timing of the DNO's determination of ANM curtailment required includes an inherent trade-off between the DNO being able to forecast network flows more precisely and so minimise headroom required for forecast inaccuracy the closer to Gate Closure (one hour ahead) as possible; vs the time needed for generators and NG ESO control room to make reasonable and cost-effective decisions.

4.2.3.2 Impact on Parties and Changes Required

NG ESO: The way in which NG ESO selects which BM Bids and Offers to accept would change, by taking into account which BMUs would have any change in output counteracted. This would reduce the need for further BM actions where these changes would previously have been counteracted. It would also require the establishment of good communication links between DNOs and NG ESO. There may be operational implications for NG ESO depending on the timing of the information from DNOs on levels of curtailment in the upcoming Settlement Period.

DNOs: This would represent a fundamental change in the operation of ANM systems by DNOs, with forecasting required for each ANM system ahead of time for each Settlement Period. It would also require the reliable communication of these forecasts to NG ESO, through improved communication links.

Generators: Generators may benefit from this change as unknown non-delivery risk would be reduced (generators would know whether or not they will be curtailed). But this solution would also likely result in higher levels of curtailment as DNOs would be forced to build in uncertainty risk when making curtailment decisions ahead of time and so allow additional headroom.

4.2.3.3 Pros and Cons

Pros:

- Reduces risk of counteraction and non-delivery by enabling NG ESO to dispatch generators in the BM with knowledge of the level of ANM curtailment.

Cons:

- The feasibility of such a system, to be rolled out consistently across all DNOs, is unproven.

- The efficiency of network use is reduced, as ANM systems are required to curtail much further in advance.
- Sunk investment in fast-acting ANM systems would be undermined.
- Increased curtailment of generators may outweigh the benefits of better coordination, particularly if low cost generation is subject to additional curtailment as a result.
- This solution only addresses the BM, not other Balancing Services.

4.2.3.4 Recommendation

This solution could have some benefits for NG ESO's procurement of Balancing Services, albeit it may also create pressures at the time at which the DNO releases its ANM curtailment information, as NG ESO's control room may have already taken many decisions ahead of that time which may be undermined by potentially material changes from ANM curtailment instructions. But more fundamentally, this solution is likely to undermine the benefit of ANM schemes, which enable high utilisation of network capacity by curtailing in real time. The solution would only resolve the issues if curtailment were effectively "firm" when communicated to NG ESO, which is likely to require ANM curtailment to be so conservative that the benefit of ANM will be undermined. It may also create contractual issues for DNOs and viability concerns for generators if curtailment suddenly increases significantly, where the business case for generators was likely based on low projected curtailment.

We anticipate that this solution is unlikely to deliver benefits, but we will carry out a high-level CBA to confirm that this is the case.

4.2.4 SOLUTION X1: IMPROVED COMMUNICATION WITH GENERATORS

4.2.4.1 Description

This is a solution to Test Cases 3A (generator defaults on Balancing Service due to constraints) and 3B (generators with ANM connection prevented from accessing Balancing Services markets), where generators with ANM connections may default or be excluded from participating in Balancing Services markets.

This solution would require DNOs to develop new operational communication links with generators, so that at defined points ahead of each time period, ANM systems could issue a signal on the likelihood of curtailment based on demand and generation forecasts. For services where participation is contractually blocked, terms would be updated under this solution to allow participation up to a pre-determined likelihood of curtailment, i.e. to allow participation when the likelihood of curtailment is low.

Forecasting of curtailment likelihood would have to be on a half-hourly basis and available at least at the day-ahead stage, to allow for aggregation of those half-hourly periods where services are required over a longer delivery window. This could be refined closer to time, for a more accurate view for shorter-term services. The specific risk tolerances for each service would be determined by NG ESO.

4.2.4.2 Impact on Parties and Changes Required

NG ESO: There would be no infrastructure changes required from NG ESO, but the terms of Balancing Services may need to be updated to allow for participation from ANM generators up to a certain level of curtailment risk. NG ESO would have to calculate the level of acceptable risk on each of its services.

DNOs: DNOs would be required to continually forecast curtailment risk for each generator behind each of their ANM schemes. This would have a material impact on DNO operations, both through the large amount of forecasting required and the high level of complexity in ANM systems, which would need to be simplified for a half-hourly forecast. Reliable communications channels would be required with generators, beyond those used currently to carry out ANM curtailment. The design of communications channels would depend on the frequency and nature of curtailment risk forecasts, which itself would depend on the specific Balancing Services covered by the solution.

Generators: Generators would be impacted as they would have better information from the DNO on curtailment risk and better access to Balancing Services markets. Systems and processes to accept and interpret the data would need to be put in place. It would also require trading strategies to be modified to take account of this better information when making operational decisions.

4.2.4.3 Pros and Cons

Pros:

- This solution enables operators of generators to make informed decisions about whether to offer Balancing Services based on the risk of default in that time period.
- Assuming a good level of accuracy in DNO demand and generation forecasts, there would be significantly lower risk of default on Balancing Services procured from ANM generators.

- This enables markets for some services to be open to more participants at times when curtailment is not expected, increasing liquidity in the markets and ultimately reducing consumer costs.

Cons:

- This is a relatively complex solution, requiring continuous short-term forecasting from DNOs and interpretation of those forecasts by generators when making decisions on which Balancing Services to offer.

- The solution risks reducing the value delivered by ANM schemes which are currently able to curtail on a sub-half-hour basis (some on second-by-second, others over a timeframe of a few minutes) which would have to be simplified to issue curtailment instructions on a less sophisticated (i.e. half-hourly) basis.

4.2.4.4 Recommendation

Improved communications on the likelihood of curtailment first relies on DNOs having the ability to forecast curtailment levels. Typically, DNOs currently have more capability for long-term (i.e. planning timescales) forecasting compared to short-term (i.e. operational timescales) forecasting. But all DNOs are progressing work in this area, which could in turn be an enabler for this solution. Assuming DNOs have that short-term forecasting capability, communication to the market on the likelihood of ANM curtailment at varying timescales is likely to derive significant benefits.

This solution requires generators to use DNO forecast information to make their operational and trading decisions, compared to solution Y1 which requires NG ESO to use that information. It is not immediately clear which of these would deliver more benefit, so we intend to subject both to a detailed CBA.

4.2.5 SOLUTION Y1: RISK-BASED BALANCING SERVICES VALUATION

4.2.5.1 Description

This is a solution to Test Cases 1A (counteraction of incrementing service by ANM), 1B (counteraction of decrementing service by ANM), 3A (generator defaults on Balancing Service due to constraints) and 3B (generators with ANM connection prevented from accessing Balancing Services markets).

This solution would see a change to the way in which NG ESO values Balancing Services to reflect the risk of non-delivery due to network issues, including faults (for example where there is a higher risk of faults driving non-delivery for generators with a single circuit connection) and ANM schemes.

NG ESO would create a risk-based framework, taking into account information from the DNOs on curtailment risk for each ANM scheme, and factoring in this risk for each Balancing Service. This would require knowledge of generators in ANM areas (or highly granular information from DNOs on a generator level), as well as forecasting of curtailment risk on an ongoing basis, similar to that in solution X1.

The risk would need to be priced into Balancing Services, as NG ESO itself manages the risk of service counteraction by ANM schemes on behalf of Balancing Services Use of System (BSUoS) payers. In doing this, NG ESO would pay for the service as if it had been delivered and waive any non-delivery penalties where non-delivery is caused by network faults (both for transmission and distribution connected users) or ANM curtailment. These non-delivery penalties vary for different Balancing Services including payment reversal mechanisms (e.g. for Balancing Mechanism), zero payment (e.g. for FFR) and contract termination over a non-delivery threshold and/or frequency (also FFR).

4.2.5.2 Impact on Parties and Changes Required

NG ESO: This solution has a high impact on NG ESO, as it manages the risk on behalf of consumers that was previously borne by generators. However, by creating a risk-based framework for dispatch, NG ESO should be well-placed to manage that risk. NG ESO would also require the ability to determine whether non-delivery was caused by network issues (in which case the generator would be paid for delivery and any non-delivery penalties/payment reversal mechanisms would be waived) or generator issues (in which case payment would not be made and any non-delivery consequences would still apply). Additionally, NG ESO may need to review and amend service terms to allow for the change in procurement of affected Balancing Services.

DNOs: This solution would require DNOs to provide forecasts to NG ESO on the likelihood of ANM curtailment for each period ahead of time and around Gate Closure for NG ESO to factor into its Balancing Service procurement and dispatch decisions. It would also require ex post reporting from the DNO to NG ESO on ANM curtailment in each Settlement Period in order for NG ESO to determine which non-delivery penalties should be waived. This would also require the establishment and maintenance of reliable communications with NG ESO.

Generators: This solution would not require any action from generators but would remove barriers to accessing Balancing Services markets by transferring risk onto NG ESO. However it may result in a loss of transparency as NG ESO factors in the risk of non-delivery due to network issues into its dispatch decisions.

4.2.5.3 Pros and Cons

Pros:

- This reduces the risk of counteraction by enabling NG ESO to “price in” the risk when analysing the price stack for a given service.
- It also enables ANM generators to participate freely in the BM, providing the risk of curtailment is sufficiently low. If the risk were too high, ANM generators could effectively be priced out of the market. NG ESO manages the risk of service counteraction by ANM systems, but (via greater forecasting and information provision from the DNO) is well-positioned to manage that risk.

Cons:

- This may be less transparent than the existing BM system, where all Bids and Offers are valued equally.

4.2.5.4 Recommendation

As with solution X1, this solution relies on DNOs’ short-term forecasting capability which is already being developed. This solution would require NG ESO to use additional information on the likelihood of ANM curtailment to inform its decision on which assets to dispatch.

It is not immediately clear whether this solution or solution X1 would deliver more benefit, so we intend to subject both to a detailed CBA.

4.2.6 SOLUTION Y2: FRAMEWORK FOR ALLOCATING NETWORK CAPACITY

4.2.6.1 Description

As with solution Y1, this is a solution to Test Cases 1A (counteraction of incrementing service by ANM), 1B (counteraction of decrementing service by ANM), 3A (generator defaults on Balancing Service due to constraints) and 3B (generators with ANM connection prevented from accessing Balancing Services markets).

This solution would see the development of a framework that makes network capacity a tradeable commodity. This would allow the market to find the most effective dispatch solution if there was sufficient liquidity in the market for tradeable capacity. Those with capacity could then choose whether to use that capacity for the provision of energy only or for Balancing Services. This would resolve conflicts by making explicit which generators have capacity (i.e. will not be subject to curtailment) and those which do not (i.e. will be subject to curtailment). Only those with capacity would contractually be able to provide Balancing Services.

Capacity could either be tradeable across all generators (with ANM generators de-rated to reflect the likelihood of curtailment during the period under consideration), or just between ANM generators within a given ANM zone, although it is unlikely to be desirable to restrict the market in this way.

As with other solutions (namely X1 and Y1), DNOs would have to forecast the likelihood of curtailment. It would be particularly important in this case that the forecasting is carried out on a consistent basis to allow for a common approach to setting market parameters.

4.2.6.2 Impact on Parties and Changes Required

The primary change would be to market rules, allowing network capacity to become a tradeable commodity. This would require material regulatory change, and overlaps with work ongoing under Ofgem's Network Access and Forward Looking Charges Significant Code Review (the "Access SCR").

NG ESO: There would be limited impact on NG ESO, as the DNOs allow capacity to be traded and market participants act accordingly. The terms of Balancing Services would need to be modified to only allow participants with sufficient network capacity at the relevant time to provide Balancing Services.

DNOs: This would require significant work from DNOs to establish a common approach to a market framework for capacity. Information would need to be made available to the market, potentially on a half hourly basis.

Generators: Generators across the board would be impacted, opening up a new way to trade and wider access to Balancing Services. Strategies would have to be put in place to participate in the new market.

4.2.6.3 Pros and Cons

Pros:

- Network capacity would be allocated to generators who value it most, and as such it would be used most efficiently.
- Removes conflicts between ANM and Balancing Services by making explicit which generators have capacity and so which can provide Balancing Services.

Cons:

- Creates difficult interactions between market outcomes and network capabilities – either DNOs will be forced to make “after-market” adjustments (recreating many of the coordination issues) or to make conservative forecasts on available capacity to allow for uncertainty.
- Fundamental change which will impact all generators connected in ANM areas (and potentially beyond), including those connected on standard terms pre-ANM.
- Highly complex, requiring a high degree of regulatory change and design of new systems by DNOs, with a common approach taken to allow for the trading of capacity.

4.2.6.4 Recommendation

At face value, this is an attractive solution, enabling the benefits of a well-functioning market to be realised in the context of allocating network capacity. But there are significant complexities around the facilitation of such a market. Capacity trading is the subject of UKPN’s Energy Exchange project[14].

> **To avoid duplication with the UKPN Energy Exchange project, we do not intend to consider it further under this project.**

[14] https://innovation.ukpowernetworks.co.uk/projects/energy-exchange/

4.2.7 SOLUTION Z1: CLASS TO ANM COORDINATION

4.2.7.1 Description

This solution, alongside Z2, is a solution to Test Cases 2A-D, which look at the issues of coordination between CLASS systems providing services to NG ESO and ANM systems.

Typically, CLASS will be implemented in areas that are dominated by demand rather than generation. This means there will be limited numbers of ANM generators, and the likelihood of conflicts with ANM operation will be relatively low. However, if the number of distributed generators in an ANM area was to increase, the probability of conflicts would increase.

Based on this assumption, this solution would see the CLASS system harmonised and coordinated with each ANM system. In this case, the CLASS system would monitor the ANM system and provide an updated export limit to the ANM (or deactivation of the ANM), reflecting CLASS actions taken and avoiding ANM counteraction of these.

If CLASS was implemented in an ANM area dominated by generation, the CLASS system would be deactivated or limited if there is a conflict with the ANM export capacity.

4.2.7.2 Impact on Parties and Changes Required

NG ESO: No impact, other than CLASS actions not being counteracted by ANM systems. We assume that CLASS will be implemented in areas that are dominated by demand rather than generation as per the feedback provided by Electricity Northwest (ENW), the only DNO to have rolled out CLASS.

DNOs: This solution requires real-time monitoring of the CLASS and ANM systems by the DNO. This would require careful decision making and coordination by the DNO regarding which of the schemes should lead the actions based on the nature of the shared area (CLASS will likely lead for demand-dominated areas and ANM will lead in generation-dominant areas). DNOs would also have to review whether, under current contractual terms with generators, they could constrain generators to allow for DNO service provision to NG ESO via CLASS.

In the case of ENW, the ANM system has the primary control logic, and as such can oversee other automated systems, including CLASS, and take avoiding actions. However, this solution should be assessed to work with other ways of implementing CLASS and ANM in parallel.

Generators: ANM generators may, in rare instances, be curtailed more frequently to allow for the provision of services to NG ESO by CLASS implemented in demand-dominated areas. ENW mitigate this with appropriate DNO conflict management techniques, such as:

- Only using CLASS in high demand areas/ times of the day where demand exceeds generation (for a demand reduction service);
- Using CLASS where it is not likely to cause an adverse ANM response if triggered;
- Allowing ANM to have sight of CLASS actions and to block ANM responses which counteract the advantages of CLASS, whilst ensuring that network limitations are not breached;

- Ensuring that CLASS can always deliver on its NG ESO contracts by ensuring there is sufficient levels of over delivery; and
- Regular monitoring of the two systems actions to see if there have been any unintended consequences and modify processes if any issues are identified.

ANM generators may not be curtailed or will see limited impact by CLASS in ANM generation-dominated areas.

4.2.7.3 Pros and Cons

Pros:

- Fully avoids CLASS and ANM actions counteracting each other and ensures service delivery.

Cons:

- The complexity of communication and monitoring infrastructure between ANM and CLASS systems may lead to a high implementation and operational cost.
- ANM generators could be artificially constrained to enable provision of CLASS services to NG ESO, presenting an opportunity cost to those generators. Balancing Services markets could be distorted if DNOs prioritise delivery of services via CLASS over service provision by ANM generators, but ENWL currently avoids this issue through the conflict management described above.
- Generation-dominated ANM areas may preclude the use of CLASS.

4.2.7.4 Recommendation

Implementation of this solution would rely on advanced real-time communication and monitoring between CLASS and ANM in order for CLASS to correctly provide the required instructions to the ANM scheme (e.g. updated export limit for the ANM generators). However, the communication and monitoring infrastructure between ANM and CLASS systems can be complex and costly to implement and operate. Also, this solution may restrict the efficiency of the ANM scheme, which should be factored into a CBA.

Based on consultation with ENW, it is understood the CLASS system would typically be implemented in areas that are dominated by demand rather than generation, hence the likelihood of conflicts with ANM operation will be low.

If CLASS and ANM systems are installed in the same area, the priority will be given to CLASS if the area is dominated by demand, and the priority will be given to ANM if the area is dominated by generation. So, only one scheme will be activated at a time and the other will be restricted. This approach is currently used by ENW. Therefore, this option will be used as a reference case for understanding the merit of solution Z2 when both schemes operate in parallel.

4.2.8 SOLUTION Z2: CLASS VISIBILITY OF ANM

4.2.8.1 Description

Like solution Z1, this solution addresses Test Case 2A-D, on coordination of ANM and CLASS systems.

This solution would see a similar monitoring scheme to solution Z1, with real-time monitoring between the CLASS and ANM systems. In this case, rather than the operation of the ANM system being modified due to CLASS actions, the CLASS system will modify its own operation to take account of ANM actions. This would ultimately ensure the level of service provided to NG ESO is as expected.

4.2.8.2 Impact on Parties and Changes Required

NG ESO: As for solution Z1, there would be no impact on NG ESO, other than CLASS actions achieving the desired effect by working in tandem with ANM systems. As such, the number of actions taken to achieve the same result can also be reduced, as no counteraction should occur.

DNOs: Like solution Z1, this requires real-time monitoring of the CLASS and ANM systems by the DNO, with the addition of some forecasting of ANM actions, to be incorporated into CLASS decision making.

Generators: This solution would not impact generators, as ANM schemes would continue to act as normal.

4.2.8.3 Pros and Cons

Pros:

- Unlike solution Z1, this does not impose artificial constraints on generators to allow for CLASS actions.
- This solution allows the DNO to better predict the level of service provided to NG ESO.

Cons:

- The implementation of this solution may be complex, including ANM forecasting capability and integration within the CLASS system.
- New power systems algorithms would be required to calculate the response of ANM-connected generators.

4.2.8.4 Recommendation

As with solution Z1, this solution relies on real-time communication and monitoring of CLASS and ANM systems with the addition of some forecasting of ANM actions. This solution would not impact the efficiency of the ANM scheme since there are no artificial constraints imposed on ANM generators. However, it could be challenging and costly for the DNO to build the ANM forecasting capability in the short term.

This solution has the potential to minimise the impact of each scheme (i.e. CLASS and ANM) on the other to meet their requirements and ensures estimation and service compensation of any potential conflict between the two systems. From early modelling on Test Case 2, we have also noticed that CLASS actions have relatively limited impact on the ANM constraints, which can possibly be compensated.

Although this solution may be difficult to implement, it may have material benefits allowing for the parallel operation of CLASS and ANM systems. Therefore, we intend to carry out a detailed CBA on this solution.

4.2.9 COMPENSATION FOR ADDITIONAL CURTAILMENT

4.2.9.1 Description

Some of the solutions considered above may result in additional curtailment for ANM Generators beyond the levels and/or circumstances under which DNOs are able to curtail those generators under their existing contractual terms.

For any of the solutions above, generators could, in theory, be compensated for additional curtailment faced. The cost of this would ultimately be borne by consumers, as higher Balancing Services costs are passed through to electricity bills.

Any compensation could be factored into NG ESO's cost stack assessment for Balancing Services, to allow for the most cost-effective solution to be taken. This could be forecast by the DNOs, with a settlement process to pay the compensation and true-up any differences between the forecast and outturn curtailment.

4.2.9.2 Impact on Parties and Changes Required

NG ESO: Depending on the solution, NG ESO may have to compensate generators that are curtailed to avoid counteraction, or to allow delivery of, a Balancing Service. This cost would have to be recovered through BSUoS charges. A settlement process would have to be established with DNOs to assess the additional curtailment and any payments to generators due as a result. NG ESO would also need a process to factor in the cost of curtailment into the price stack, possibly through DNO forecasting of curtailment needs.

DNOs: DNOs would be required to establish the additional curtailment undertaken through a change in the operation of ANM schemes, which again would depend on the solution under consideration. A settlements process would have to be undertaken with NG ESO and generators. Additionally, new commercial terms would have to be established with generators to allow for the additional curtailment and subsequent compensation. If forecasting of curtailment is required for NG ESO's determination of costs, this would present a challenge and additional cost to DNOs.

Generators: Generators that face additional curtailment as a result of the implementation of the solutions described above could be appropriately compensated for that curtailment. Generators that cause a greater need for curtailment may find themselves priced out of Balancing Services when the cost of that compensation is factored into the price stack.

4.2.9.3 Pros and Cons

Pros:

- This would make changes to commercial terms, which may be required for many solutions, easier to implement for DNOs.

Cons:

- Compensation would lead to increased consumer costs, albeit a detailed CBA will be required to first demonstrate that those additional costs are outweighed by the resulting benefits.

- A new financial settlement scheme between NG ESO, DNOs and generators may be complex to implement.

4.2.9.4 Recommendation

The costs and benefits of compensation should be considered alongside all solutions where it is appropriate to implement, during the course of the full CBA process.

4.3 PRELIMINARY SOLUTIONS SHORTLIST

Based on the above, the preliminary solutions shortlist we propose to consider for further exploration in WS4 is as follows:

- Solution W1: Parallel decrementing instruction to DER and ANM;
- Solution W2: Preparatory incrementing instruction to ANM, but only in the context of Frequency Response;
- Solution X1: Improved communication with generators;
- Solution Y1: Risk-based Balancing Services valuation; and
- Solution Z2: CLASS visibility of ANM.

We will further explore this set of preliminary solutions early in WS4 and subsequently recommend a final set of solutions to be investigated and modelled in detail in throughout WS4.

5 CONCLUSIONS

There is a broad range of possible solutions to the issues identified in the Test Cases. An initial assessment of those solutions reveals a preliminary shortlist of options to be taken forward for further assessment, which involve a combination of:

- Reconfiguring ANM schemes;
- Improving information exchanges between DNOs, NG ESO and generators; and
- Amending market rules for Balancing Services.

The preliminary solutions shortlisted need thorough analysis before selecting the optimal solution. That assessment will consider:

- The implementation and ongoing costs of the solution;
- The impact on levels of ANM curtailment, noting that any increase in ANM curtailment creates cost for consumers;
- The impact on clearing prices for Balancing Services; and
- The impact on non-delivery risk of Balancing Services.

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