NG ESO and WPD

OPTIMAL COORDINATION OF ACTIVE NETWORK MANAGEMENT SCHEMES WITH BALANCING SERVICES MARKETS

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EXECUTIVE SUMMARY

Active Network Management (ANM) schemes are becoming increasingly widespread on GB distribution networks, alongside the development of some 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 network more quickly and at lower cost by actively managing generation output to avoid breaching existing network limits, rather than undertaking network reinforcement. ANM schemes benefit consumers by minimising the costs of connecting new, often 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. Issues are most notable if the ANM scheme takes an action to manage generation in a given area which directly counteracts the effect of a Balancing Service procured by NG ESO – for example one generator increases output as instructed by NG ESO but in response the ANM scheme curtails another. This presents a risk to security of supply. It also increases costs to consumers as NG ESO must instruct another generator elsewhere to increase output to achieve the outcome it requires.

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 first two workstreams, through which we have identified the range and scale of ANM schemes in use on the networks or planned for deployment; qualitatively described the coordination issues which arise; and approximated the benefits of optimal coordination.

There is currently (July 2020) 1.3GW of generation connected to distribution ANM schemes (summarised in Table 1-1) and at least a further 3.8GW with an accepted connection offer. Most of that generation is renewable (primarily wind and solar) but there are some other technologies including gas generation. There is also around 14GW of generation connected to the distribution network behind ANM constraints but whose output is not managed by the ANM system.

Table 1-1: Summary of ANM connected generation and planned development by DNO

DNO	Volume of ANM Generation (MW)	Planned Development
Scottish Power Energy Networks	152	Dumfries and Galloway wide area scheme managing interacting transmission and distribution constraints. Transmission ANM being developed which will manage transmission constraints
Scottish and Southern Energy Networks	160	South West Operational Tripping Scheme will result in ~60% of the Southern region being managed by ANM
Electricity North West	0	Licence area wide scheme planned
Northern Powergrid	770	Further schemes as needed. Latest system is fully scalable
UK Power Networks	114	Further schemes in development
Western Power Distribution	108	High volume of accepted offers in ANM-managed areas likely to increase curtailment
Total	**1,304**	

There are currently no ANM schemes that manage transmission connected generators, although NG ESO's Generation Export Management Systems (GEMS) are in development. These are similar in principle to distribution ANM systems, but will have some fundamental differences, including likely direct interaction with Balancing Services and compensation for generators that are curtailed. Some transmission constraints are managed by distribution ANM schemes. Additionally, NG ESO manages constraints through the Balancing Mechanism, and is seeking further solutions through its Constraint Management pathfinding project.

There is a broad range of ANM schemes either in operation or in development. The simplest schemes manage power flows at a single constraint location by controlling the output of a single generator. The more complex systems manage multiple inter-related constraints with multiple generators. There are also several ANM schemes in place which manage transmission constraints.

Many of those schemes monitor power flows at the interface between the transmission and distribution system to remain with a fixed level of reverse power flow. However, there are more complex combinations of schemes in development which will actively manage constraints on both the transmission and distribution networks.

Based on ANM schemes deployed to date and in development, we have determined a high-level estimate of the impact on costs to consumers of poor coordination between the Balancing Mechanism and ANM schemes in the cases we have identified. A more detailed assessment of the benefit of possible solutions will be undertaken in later workstreams. Our initial high-level assessment focuses on:

- The cost to NG ESO (ultimately borne by consumers) of dispatching additional volumes in the Balancing Mechanism to replace those which are counteracted by ANM schemes; and

- The impact on Balancing Mechanism clearing prices of low liquidity if generators connected to ANM schemes were to be blocked from, or choose not to, participate.

In both cases, the benefit calculated is a potential future benefit as it assumes high levels of participation in the Balancing Mechanism from distributed assets. In order to quantify the benefits, we have used 2019 Balancing Mechanism data and assumptions on bidding behaviour for each generation technology type considered (wind, solar and gas). This high level assessment shows potential costs of poor coordination of around £8.5mn per year (based on 2019 as an example year) for the Balancing Mechanism alone.

1 PROJECT OVERVIEW

WSP[1], Cornwall Insight[2] and Complete Strategy[3] are undertaking a Network Innovation Allowance (NIA) funded project on behalf of National Grid Electricity System Operator[4] (NG ESO) and Western Power Distribution[5] (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[6] (FES) and System Operability Framework[7] (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 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).

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

Similarly, the Network Options Assessment[8] (NOA) identifies increasing constraint issues on the transmission system, driving Transmission Owners (TOs) and NG ESO to use ANM on the transmission system to optimise power flows at constraint boundaries.

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[9] 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.

[8] https://www.nationalgrideso.com/document/162356/download
[9] For simplicity and consistency any action taken by NG ESO will be referred to as "Balancing Services" in this document. See Section 2.3 for further info on these

For example, the Future Worlds[10] developed under the Open Networks Programme[11] considered different approaches to the coordination of procurement of flexibility services from DER by both the future Distribution System Operator (DSO) and NG ESO.

We expect 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.

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

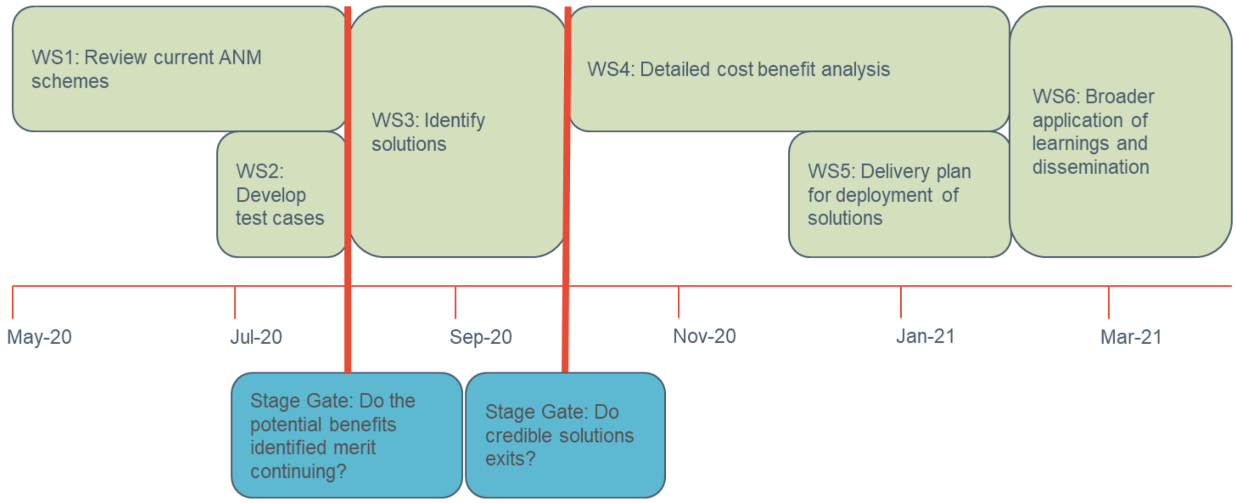

Figure 1-1: Project outline

1.3 PURPOSE OF THIS REPORT

This report concludes the first phase of the project and covers the findings of both WS1 and WS2 as shown in Figure 1-2.

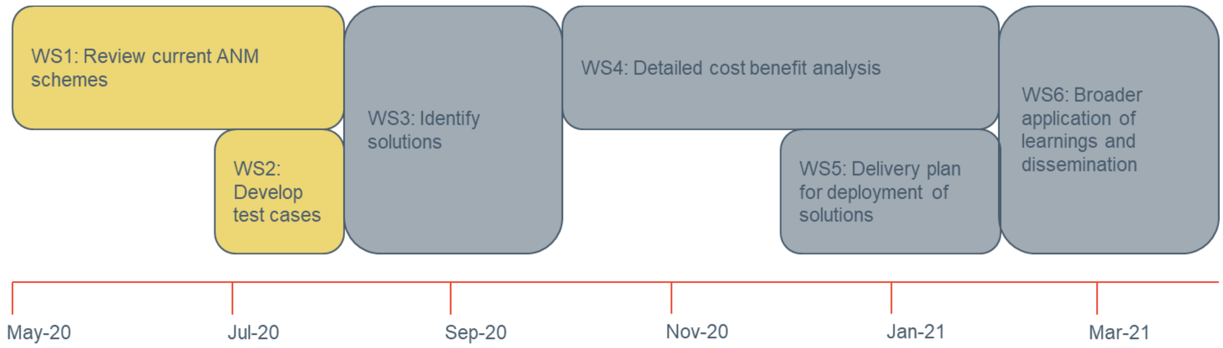

Figure 1-2: Focus of this report

It focuses on:

- Establishing terminology to be used for the remainder of the project (Section 2);
- Understanding the range and scale of ANM schemes currently deployed (Section 3);
- The risks of ANM schemes which are not coordinated with Balancing Services markets (Section 4);
- The definition of Test Cases to be used further in the project (Section 5);
- High level assessment of benefits in respect of selected Test Cases (Section 6); and

- Existing coordination approaches, including restrictions on the participation of DER connected to ANM schemes in providing Balancing Services to NG ESO; and existing coordination between DNOs and NG ESO (Section 7).

The information is drawn from publicly available sources and engagement with each of the DNOs, NG ESO and the project Advisory Group which consists of network companies, generators, and technology providers.

2 TERMINOLOGY

This section establishes key definitions that will be used throughout the project. It also gives some further background on the types of ANM scheme that will be considered.

2.1 ACTIVE NETWORK MANAGEMENT SCHEMES

2.1.1 DISTRIBUTION ANM SCHEMES

A widely recognised definition of ANM comes from the Energy Networks Association[12] (ENA):

Using flexible network customers autonomously and in real-time to increase the utilisation of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs

While this definition is widely recognised, our engagement with Stakeholders has suggested we use a more focused definition that focuses on the use of ANM to resolve network constraints. Our intended definition, therefore, is:

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

For the purposes of this report, we are particularly interested in ANM schemes on the distribution networks. This is because distribution ANM schemes (including those managing flows at the transmission to distribution interface) are already widespread and being deployed as business as usual, unlike GEMS (see Section 2.1.2) which is not expected to be operational until 2022. Recognising that currently it is primarily generators affected by ANM schemes, we will focus on generators (as a subset of DER) rather than demand on ANM schemes.

We also focus solely on those schemes which are implemented to reduce connection costs. That is, the reinforcement costs which are avoided through curtailment risk would otherwise have been borne largely by the connecting generator (through their connection charge). Compensation for curtailment is therefore realised upfront at the time of connection and not an ongoing basis when curtailment occurs.

Finally, we focus on permanent schemes, rather than temporary ANM schemes, which are only in place to enable quicker connections while network reinforcement is carried out.

[12] https://www.energynetworks.org/assets/files/news/publications/1500205_ENA_ANM_report_AW_online.pdf

We recognise that, in the future, the purpose of ANM-type technology may not simply be to increase the utilisation of network assets to facilitate new connections without the need for network reinforcement, but the optimisation of energy assets more generally. This may be to enable optimised use of local energy assets, reducing use of the networks and consequently reducing losses. This project will focus primarily on those schemes managing network constraints; in this context, the primary purpose of ANM remains the optimisation of network asset utilisation and so the primary purpose of ANM schemes we are interested remains the purpose from the ENA definition. That is, if a generator is looking to connect to a constrained part of the network (generally thermal or voltage constraints), a cheaper and quicker connection may be offered by the DNO if the generator agrees to take on some curtailment risk, where a conventional connection agreement may be prohibitively costly to the generator and considerably slower.

The ENA definition does not explicitly mention constraints, and we recognise that ANM schemes may be used more widely for general power flow management. However, the issues around coordination with NG ESO Balancing Services actions arise specifically from constraints, and this is made clear in the definition we use.

Connections under an ANM scheme are also sometimes referred to in other documentation as “non-firm” or “flexible” connections. For the avoidance of doubt, we do not use these terms as they can be interpreted in different ways (see Section 2.2 for clarification on terminology for generator types). The level of risk taken depends on the design and operation of the specific ANM scheme. Generators on distribution ANM schemes are not directly compensated on an ongoing basis for any curtailment – the benefit generators derive from being connected via an ANM scheme is derived upfront through a quicker and cheaper connection. This is a fundamental difference to transmission-connected generators behind constraints, which are compensated for curtailment through the Balancing Mechanism. The ANM benefit of cheaper connections for generators is a consequence of the existing “shallowish” distribution connection charging boundary, under which distribution connectees are required to fund the cost of assets to connect them to the wider network and a proportion of the costs of upgrades on the wider network to facilitate their connection. The distribution connection charging boundary is within scope of Ofgem’s Network Access and Forward Looking Charges Significant Code Review. Shortlisted options[13] all move to a “shallower” or “shallow” connection charging boundary under which distribution connectees would only be required to fund the costs of assets to connect them to the wider network. A shallow connection charging boundary would have a significant impact on the use of ANM as its value to generators would be reduced; however, it would likely still have material value through facilitating quicker connections (i.e. enabling new generators to connect while network reinforcement is carried out).

Most schemes operate on a “last in first off” (LIFO) principle. Under this approach, constraints are managed by curtailing generators in the order they connected to the network, with the last to connect being the first to be curtailed when the constraint is reached. This prevents generators connected earlier being negatively affected by generators connecting later. While this is the most common design, some schemes have used a pro-rata curtailment system, whereby all generators on an ANM

[13] https://www.ofgem.gov.uk/publications-and-updates/electricity-network-access-and-forward-looking-charging-review-open-letter-our-shortlisted-policy-options

scheme are curtailed proportionally based on their contribution to the constraint. As such, generators connecting earlier and experiencing relatively little curtailment may see curtailment levels increase as more generators connect.

Curtailment of ANM generators is typically open ended. DNOs often informally share details of expected curtailment from power flow model runs with customers to inform customers' investment decisions, but the level of curtailment is not typically included in connection agreements. A clear exception to this is Electricity North West's (ENWL's) use of a curtailment index – see Section 3.2.3.

2.1.2 GENERATION EXPORT MANAGEMENT SYSTEMS

Generation Export Management Systems (GEMS) can, to a certain extent, be considered the transmission equivalent of ANM. Unlike ANM, GEMS is not yet in widespread use.

While there are some similarities, when deployed, GEMS will have some fundamental differences to ANM schemes currently in use on the distribution network. Most notably, GEMS is likely to have a direct interaction with Balancing Services. The Balancing Mechanism is already used to manage constraints on the transmission network by curtailing generators (at their Balancing Mechanism Bid price) to resolve transmission constraints.

More detail is provided on GEMS in section 3.3.

2.1.3 INNOVATION IN ANM

The early development of ANM schemes was largely through DNO-led innovation schemes. While many new schemes are now rolled out under business as usual arrangements following those early innovation trials, DNOs continue to develop the sophistication of ANM schemes through innovation projects. The most notable completed or ongoing innovation projects for which impact on this project include:

- UK Power Networks (UKPN) – Flexible Plug and Play[14], which demonstrated that cost-effective connection of DER could be achieved through innovative technological commercial arrangements;
- UKPN and NG ESO – Power Potential[15,16], which is enabling DER to alleviate transmission voltage constraints through the trialling of a market for the provision of reactive power;
- Scottish and Southern Energy Networks (SSEN) – Orkney Smart Grid Registered Power Zone[17], which was devised to make better use of the existing network by instructing generators to control their output to match network capacity;
- Scottish Power Energy Networks (SPEN) – Dumfries and Galloway ANM[18]; which is seeking to use DER and an ANM system to manage transmission constraints;

[14] https://innovation.ukpowernetworks.co.uk/projects/flexible-plug-and-play/.
[15] https://www.nationalgrideso.com/future-energy/innovation/projects/power-potential
[16] https://innovation.ukpowernetworks.co.uk/projects/power-potential/
[17] https://www.ssen.co.uk/OrkneySmartGrid/
[18] https://www.spenergynetworks.co.uk/pages/dumfries_and_galloway_integrated_network_management.aspx

- ENWL – Customer Load Active System Services (CLASS)[19], under which voltage management technologies on distribution networks are used to intentionally alter the level of power consumption at lower voltage connection levels;
- Northern Powergrid (NPg) – Customer Led Network Revolution (CLNR)[20], which assessed the potential of novel smart grid technologies;
- Western Power Distribution (WPD) – Lincolnshire Low Carbon Hub[21], which was designed to test a variety of innovative techniques to allow low carbon generation to connect to electricity networks;
- WPD/UKPN and NG ESO – South West Peninsula and South East Coast Regional Development Programmes (RDP), which are being progressed to provide detailed analysis of areas of the network that have large amounts of DER to enable more DER to connect without reinforcement taking place; and
- All network companies are also progressing the Open Networks Project which includes assessment of the conflicts and synergies between one or more services required by different system operators (i.e. NG ESO and a DSO).

We have used the (in some cases preliminary) findings of these projects to inform our understanding of the risks of uncoordinated ANM schemes and direction of travel for future ANM schemes which may give rise to future conflicts and synergies between ANM schemes and Balancing Services.

Further detail on each of the projects is included in Appendix A.

2.2 TYPES OF DER

In order to avoid any confusion on terminology, we will consider the following types of generator:

- **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; and
- **ANM generator.** Generator which is subject to curtailment by an ANM system.

Generators can of course move between these groups – for example, a deployment of a new ANM scheme would likely result in a number of generators moving from standard connection to non-curtailable in an ANM area. It is important to note that this change is entirely out of a given generator's control and they may not be aware that it has taken place, as it is driven by the action of other

[19] https://www.enwl.co.uk/zero-carbon/innovation/key-projects/class/
[20] http://www.networkrevolution.co.uk/
[21] https://www.westernpower.co.uk/projects/the-low-carbon-hub

generators connecting in the area electing for an ANM connection rather than to fund network reinforcement through their connection charge.

2.3 BALANCING SERVICES MARKETS

This project is considering the interaction between ANM and the Balancing Services markets. This section gives a brief overview of the Balancing Services we will consider.

NG ESO procures a range of Balancing Services from users connected to the transmission and distribution network, including DERs. These include:

- Balancing Mechanism;
- Frequency response;
- Reserve services (including Short Term Operating Reserve (STOR) and Fast Reserve);
- Reactive power, including NG ESO’s high voltage pathfinding project;
- Optional Downward Flexibility Management (ODFM); and
- NG ESO pathfinding projects, including stability and constraint management.

2.3.1 BALANCING MECHANISM

The Balancing Mechanism (BM) is the main mechanism for balancing the system and managing transmission constraints in real time. It operates from one hour before delivery, although NG ESO can also take early actions with certain generators or by trading on power exchanges.

For each Settlement Period, the BM operates from one hour before the start of that Settlement Period (“Gate Closure”) until the end of that Settlement Period. Participation is mandatory for licensed generators and suppliers. Larger distribution-connected generators can also participate via a Bilateral Embedded Generation Agreement (BEGA). Smaller generators can participate through an Additional Supplier Balancing Mechanism Unit (BMU), and small generation and DSR can participate through Virtual Lead Parties.

All BM Participants provide Final Physical Notifications (FPNs) by BMU ahead of Gate Closure which reflect that BMU’s expected output or demand. BM Participants also submit:

- Bids, which represent the price that a generator would be willing to pay to reduce its output compared to its FPN; and
- Offers, which represent the price that a generator would require to increase its output compared to its FPN.

NG ESO selects the lowest cost "stack" of Bids and Offers to resolve constraints and balance the system in each Settlement Period to dispatch through Bid Offer Acceptances (BOAs). BM

Participants are then paid as bid. There is effectively no restriction on prices for Offers[22], but prices for Bids from licensed generators that are behind transmission constraints are limited to short run marginal cost, accounting for maintenance, ramping down and reasonable profits from opportunity cost. Ofgem monitors compliance with this cap on Bids. Many generators choose to Bid at marginal price regardless of their location in relation to constraint boundaries to avoid inadvertent non-compliance. A non-delivery payment mechanism ensures a party is never better off having not delivered in the BM – but equally, no penal charge is applied for non-delivery.

2.3.2 FREQUENCY RESPONSE[23,24]

NG ESO has a licence obligation to maintain the frequency of the network at a level of ±1% of the nominal system frequency, set at 50.00Hz, which means that sufficient generation and DSR must be procured to manage any events that may lead to a frequency variation. System frequency will change when there is an imbalance in the energy added to the system by generators and the energy taken off the system by demand consumers. This imbalance will either speed up or slow down the frequency of the grid, and frequency response is the Balancing Service used to counteract this change.

Frequency response is provided either on a dynamic or a static basis. Dynamic response is used to continuously follow and control minor deviations in frequency due to small imbalances in generation and demand on a second by second basis. Static response is triggered at a defined frequency deviation and is used, in conjunction with dynamic response, to contain large frequency events such as generator or demand trips. Frequency response products are provided either through the mandatory requirement or through a commercial arrangement.

NG ESO has forecast that the baseline frequency response requirement will remain broadly the same over time but there will be an increase in the variability of their requirement closer to real time. This variability will also increase in size as system inertia decreases and demand behaviour becomes increasingly reactive to market signals. Details of the different frequency response services are given below in Table 2-1.

[22] Central systems impose a de facto £99,999 limit on offers, but that limit does not typically influence bidding behavior.
[23] Frequency response services, National Grid ESO https://www.nationalgrideso.com/industry-information/balancing-services/frequency-response-services
[24] "Product Roadmap for Frequency Response and Reserve," National Grid, Warwick, United Kingdom, Dec., 2017. https://www.nationalgrid.com/sites/default/files/documents/Product%20Roadmap%20for%20Frequency%20Response%20and%20Reserve.pdf

Table 2-1: Response times, durations and minimum capacities of the range of frequency response services

Service Type	Service	Response Time	Response Duration	Minimum Capacity
Mandatory Frequency Response	Primary Frequency Response	<10 secs	20 secs	TO dependant: NGET ≥ 100MW SP ≥ 30MW SHET ≥ 10MW
	Secondary Frequency Response	<30 secs	30 mins	
	High Frequency Response	<10 secs	Indefinite	
Commercial Frequency Response	Primary Firm Frequency Response	<10 secs	20 secs	≥ 10MW
	Secondary Firm Frequency Response	<30 secs	30 mins	≥ 10MW
	High Firm Frequency Response	<10 secs	Indefinite	≥ 10MW
	Dynamic Containment Response	>0.5 secs, <1 second	15 mins	TBC
	Low Frequency Static Response	<1 second	30 mins	1MW
	Dynamic Low High Reponses	Combination	Combination	1MW

NG ESO is in the process or removing the static variant of frequency response and replacing the three dynamic products with three new products: Dynamic Containment, Dynamic Moderation and Dynamic Regulation.

Delivery of the service is monitored on a second by second basis to ensure that the plant is responding to changes in system frequency according to its contract. If not, payments for the window of non-delivery are set to zero, with contract termination if non-availability occurs more than three times in any given month.

2.3.3 RESERVE[25]

NG ESO needs the ability to source extra power in the form of either increased generation or demand turndown to deal with unforeseen demand increases and generation unavailability. The current range of reserve services is made up of products that require differing response times so that operating reserve levels can be maintained. Reserve is manually instructed after automatic frequency response

[25] Reserve Services, National Grid ESO https://www.nationalgrideso.com/industry-information/balancing-services/reserve-services

services are delivered. Reserve can be upward (an increase in generation/decrease in demand) or downward (a decrease in generation/increase in demand). Reserve is also used to describe the actions NG ESO takes to ensure that sufficient upward and downward flexibility is available.

The amount of reserve procured through the markets varies considerably depending on the conditions on the day and what has been economically tendered. NG ESO has forecast that the baseline reserve requirement will remain broadly similar but there will be an increase in the variability of its requirement closer to real time. The predicted reduction in system inertia is not anticipated to affect reserve requirements as they are mainly driven by the size of the largest loss rather than the speed at which that loss is felt. Details of the different reserve services are given below in Table 2-2.

Table 2-2: Response times, durations and minimum capacities of the range of reserve services.

Service Type	Service	Response Time	Response Duration	Minimum Capacity
Reserve	Fast Reserve	Start in 2 mins, full output by 4 mins	15 mins	25MW
	BM-STOR	Typically 20 mins	2 hours	> 3MW
	Non-BM STOR	Typically 20 mins	2 hours	> 3MW
	Super SEL	Max notice period 6 hours	As agreed	>10MW
	BM Start-up	89 mins	As agreed	
	Replacement Reserve	< 30 minutes	15 mins	> 1MW
	Demand Turn-Up	Average notice period 6-8 hours	Average duration 3-5 hours	> 1MW

2.3.4 REACTIVE POWER[26]

The flows of reactive power on the system affect voltage levels. Unlike system frequency, which is consistent across the network, voltages experienced at points across the system form a 'voltage profile', which is uniquely related to the prevailing real and reactive power supply and demand. NG ESO must manage voltage levels on a local level to meet the varying needs of the system. Without

[26] Reactive power services, National Grid ESO https://www.nationalgrideso.com/industry-information/balancing-services/reactive-power-services

the appropriate injections of reactive power at correct locations, the voltage profile of the transmission system will exceed statutory planning and operational limits.

Transmission connected generators with a capacity over 50MW are required to provide reactive power services, while other providers can participate in the enhanced reactive power service (ERPS). In reality, the ERPS service has not been used for some time.

The way reactive power services are procured has evolved, with new solutions sought through NG ESO's high voltage pathfinding projects. Both transmission and distribution connected providers can participate. To date, the service has been tendered for in the Mersey region, with another tender in the Pennine region after considering lessons learnt.

Additionally, NG ESO partnered with UKPN to launch the Power Potential project, which aims to create a new reactive power market for DER and generate additional capacity on the network. See Appendix A, Section 9.1.6 for more detail on Power Potential.

2.3.5 OPTIONAL DOWNWARD FLEXIBILITY MANAGEMENT[27]

When demand is low, there may be a requirement for additional flexibility to balance generation and demand, as well as to achieve sufficient negative reserve. Restrictions associated with COVID-19 were expected to present lower demand periods for longer durations in 2020. To help manage these changing system conditions, NG ESO implemented the ODFM service across summer 2020 as a time-limited service to overcome the immediate issues, ahead of the intended implementation of a more robust enduring service in the future. ODFM is a service which allows NG ESO to access downward flexibility that is not currently accessible in real time and expand their ability to control the output from providers that are not currently accessible through the BM and the Platform for Ancillary Services (PAS).

To participate in this service, participants must[28]:

- Be capable of sustaining service delivery for a minimum of 3 consecutive hours;
- Be sized at 1MW or more;
- If Generation, be capable of reducing to 0MW and maintaining for the specified time period;
- If Demand, be capable of increasing and sustaining demand for the specified time period;
- Be capable of following pre-agreed min/max ramp up and ramp down rates;
- Not be separately registered as BM Units or otherwise active in the Balancing Mechanism;

[27] Optional Downward Flexibility Management (ODFM) Service Documents, National Grid ESO https://data.nationalgrideso.com/ancillary-services/optional-downward-flexibility-management-odfm1

[28] Optional Downward Flexibility Management Guidance Document, National Grid ESO, May 27, 2020 https://data.nationalgrideso.com/backend/dataset/812f2195-4e96-4bfd-8bf0-06c3d0126c57/resource/1b2d5573-8b91-4608-8082-d93815d970bc/download/odfm-guidance-doc-v.3-19.05.20.pdf

- Not be participating in or contracted to any other balancing/flexibility or related services during periods when the service is offered; and
- Not have a condition in their DNO connection agreement whereby they are signed up to an ANM scheme.

2.3.6 NG ESO PATHFINDIN PROJECTS[29]

2.3.6.1 Stability Pathfinding Project

This proof of concept service aims to lower the ESO's costs by contracting for stability services such as Inertia, Short Circuit Levels and fast acting voltage support. NG ESO has agreed contracts with five parties, worth £328mn over a six-year period, to provide stability services through this first phase of its stability pathfinder project. The five successful parties will either build new assets or modify existing assets to provide the stability services to NG ESO. The stability services required are inertia, fast acting dynamic voltage, and short circuit level.

The key service to be provided is inertia, which contributes to slowing the rate of change of frequency and better enables stability of voltage and frequency. This has traditionally been provided by using the kinetic energy in the spinning parts of large generators that were providing electricity onto the grid. The new approach constitutes a 0MW service, with providers classed as unavailable when exporting or importing (other than for the purposes of the stability service). In total, the contracts are procuring 12.5GVAs of inertia, the equivalent provided by approximately five coal fired power stations.

2.3.6.2 Constraint Management Pathfinding Project

This pathfinder seeks to assess alternative options to the BM for relieving constraints and reducing the need for network investment. It is yet to procure any services, with a request for information launched in December 2019. Subject to the outcome of this, a tender launch is expected in 2020.

Requirements for this service will be highly locational, relating to specific transmission boundaries associated with constraint. Energy absorption will typically be required in the north (the absorbing/exporting zone), and either a mirroring service in the south (the importing zone), or a BM action.

[29] Network Development Roadmap, National Grid ESO https://www.nationalgrideso.com/research-publications/network-options-assessment-noa/network-development-roadmap

3 RANGE AND SCALE OF ANM SCHEMES

ANM schemes can range from simple systems controlling the output of a small number of generators to manage a single network constraint; through to systems controlling many generators across a wider area to manage multiple interdependent constraints. This section seeks to explore the range of ANM schemes currently deployed and to understand the volumes of generation connected to each type. Information has been provided by the DNOs in respect of ANM schemes in each area.

3.1 GB SUMMARY

There is currently 1.3GW of generation connected to distribution ANM schemes across all the DNOs and 3.8GW from UKPN and WPD alone with an accepted connection offer. Most of that generation is renewable (primarily wind and solar) but there are other technologies including gas generation. There is also around 14GW of non-curtailable distribution connected generation in ANM areas.

The amount of ANM connected generation is expected to grow substantially in the future, with many DNOs planning schemes that will cover several GSPs or, in some cases, entire licence areas. For most DNOs, plans are in place to expand or introduce new schemes through the early 2020s. Many schemes have been developed, or continue to be developed, by innovation projects. These are discussed for each DNO individually in the sections below, and in detail in Appendix A.

There are a broad range of ANM schemes either in operation or in development. The simplest schemes manage power flows at a single constraint location by controlling the output of a single generator. The more complex systems manage multiple interrelated constraints with multiple generators. There are also several ANM schemes in place which manage transmission constraints. Many of those schemes monitor power flows at the interface between the transmission and distribution system to remain with a fixed level of reverse power flow. However, there are more complex combinations of schemes in development which will actively manage constraints on both the transmission and distribution networks.

The growth in scale and complexity of ANM schemes has been enabled by the development of systems that are able to monitor complex power flows over multiple constraints in real time and can be scaled over entire licence areas. This development has also led more DNOs to integrate ANM operations with standard control room operations, rather than have distributed servers separately managing ANM schemes.

But despite ANM schemes typically having a similar objective, there are substantial differences in the way schemes operate between DNOs. One of the key areas of difference is the response time of the ANM system, with some sub-second systems, and others that take up to a few minutes to respond to changes in power flows. This is driven by an inherent trade-off between the upfront cost and complexity of a fast acting scheme against the additional benefits delivered from faster actions which removes the need for “pre-event” curtailment.

Another key differentiator between ANM schemes is the curtailment logic. Many schemes use a LIFO stack, with varying use of sensitivity factors, which adjust the stack based on the effect each asset has on a given constraint. Other systems use a curtailment index, whereby all ANM connected generators will be curtailed equally until an agreed threshold is met for a given generator, at which point that generator would move to the bottom of the curtailment stack.

Different ANM schemes and planned developments are discussed for each of the DNOs in section 3.2, with a high level summary provided in Table 3-1.

Table 3-1: Summary of ANM connected generation and planned development by DNO

DNO	Volume of ANM Generation (MW)	Planned Development
SPEN	152	Dumfries and Galloway wide area scheme managing interacting transmission and distribution constraints. GEMS will later manage transmission constraints
SSEN	160	South West Operational Tripping Scheme will result in nine GSPs in the Southern region (~60% of the area) being managed by ANM
ENWL	0	Licence area wide scheme planned
NPg	770	Further schemes as needed. Latest system is fully scalable
UKPN	114	Enterprise-wide system now in place across the network, with the timeline of rollout driven by constraints materialising
WPD	108	High volume of accepted offers in ANM-managed areas likely to increase curtailment
Total	**1,304**	

3.2 REGIONAL VARIATIONS

The extent of ANM schemes varies significantly between each DNO area, as summarised in the following subsections.

3.2.1 SCOTTISH POWER ENERGY NETWORKS

SPEN currently has two ANM schemes in operation, each covering a GSP area, in Dunbar and Berwick. Both schemes arose from the Accelerating Renewable Connections[30] (ARC) project. They were installed to remove the need to upgrade transformers. In total, 152MW of generation is managed by the schemes, primarily onshore wind (116MW from eight sites) with the balance from one waste

[30] ARC Closedown Report, SP Energy Networks, March 31, 2017
https://www.spenergynetworks.co.uk/userfiles/file/ARC_Closedown_Report.pdf

incineration site (36MW). Further, there is around 114MW of generation capacity connected to the Dunbar and Berwick GSPs that is not managed by the ANM schemes (i.e. non-curtailable generators in an ANM area).

The learnings from these schemes are being used by SPEN for a new, wide area ANM scheme in Dumfries and Galloway, supported by £8mn of Innovation Roll-out Mechanism funding from Ofgem. This differs in that it will alleviate both transmission and distribution network constraints by actively managing distributed generation across the 11 GSPs in the area, although once the GEMS system is in place in South West Scotland, this will address transmission constraints by issuing instructions to participating DER via the SPEN ANM scheme as appropriate. Around 500MW of generation is connected in the area with a further 400MW contracted. The sites that will most benefit from the ANM scheme are five sites (totalling 120MW) that are currently on a load management system (LMS), and so experience hard tripping to alleviate constraints. Further detail on the Dumfries and Galloway project is in Appendix A. The Dumfries and Galloway scheme will incorporate some coordination with NG ESO, which is highly relevant for this project and is detailed in Section 7.2.

SPEN has longer term plans to roll out ANM schemes across both of its licence areas, firstly in the South Scotland area in 2021 and the Merseyside and North Wales area in 2022.

3.2.2 SSE NETWORKS

SSEN has four ANM schemes in place; three in the North Scotland licence area (Orkney, Shetland and Western Isles) and one in the Southern licence area (Isle of Wight). All manage both island-based and island to mainland constraints, but vary in their size and complexity. In total, around 43MW of capacity has been connected on the ANM schemes, with a further 40-50MW of additional capacity made available by the ANM schemes which has not yet been used. The connected capacity consists of 43MW of wind, solar and tidal capacity.

The scheme on Orkney was implemented by the Orkney Smart Grid project, which later became the Orkney Smart Grid Registered Power Zone (RPZ)[31]. 23 generators are subject to ANM control on the scheme across nine zones. One constraint managed by the system – the connection to the mainland – may be alleviated with a new High Voltage Direct Current (HVDC) transmission link, depending on Ofgem's final funding decision[32]. However, ANM managed constraints on the island will remain.

The Shetland ANM scheme was introduced through the Northern Isles New Energy Solutions (NINES) project[33]. Shetland is not currently connected to the national transmission system, and therefore the coordination issues with NG ESO actions are not relevant for this ANM scheme. Four generators are managed under the scheme, which previously also managed a grid-scale battery and 234 homes providing demand side response through electrical heating control as part of the innovation project.

[31] The Orkney RPZ, SSEN and University of Strathclyde, November 2007 https://www.ssepd.co.uk/WorkArea/DownloadAsset.aspx?id=992
[32] https://www.ofgem.gov.uk/publications-and-updates/orkney-transmission-project-conditional-decision-final-needs-case
[33] NINES Project Closedown Report, SSEN, April 2017 https://www.ssepd.co.uk/WorkArea/DownloadAsset.aspx?id=13343

The ANM schemes on the Western Isles and Isle of Wight are both much simpler, with one generating site managed by each on a single constraint under both schemes.

Response times for SSEN's ANM systems are generally within 30 seconds, which it is looking to reduce to sub-five second timescales. There is an ambition to move to sub-second ANM systems, which would allow replacement of inter-tripping schemes that manage transmission network constraints. The systems used for the ANM systems are being centralised and integrated with SSEN's control rooms, allowing for the reconfiguration of curtailment logic and operation of the scheme if required.

SSEN is also part of the South West Operational Tripping Scheme (SWOTS). This will see a further nine GSPs in the Southern area become ANM-enabled by October 2021, covering around 60% of the licence area. Around 1.3GW of capacity will be subject to ANM control once the systems are fully rolled out and operational. Although not currently activated, the requirement for a future ANM scheme has been known for several years, so ANM clauses have been included in connection agreements, which will be retrospectively activated.

3.2.3 ELECTRICITY NORTHWEST

ENWL does not have any current ANM schemes in operation. The DNO has looked at local systems in the past but has found little need as there are few constraints on its network. Small projects that have been explored were dropped due to cost or timescale limitations.

ENWL is planning to roll out an ANM scheme across its entire licence area in 2021. This will interface with its central management system, fault restoration systems, and other existing network automation systems (such as Smart Street and CLASS, which uses network assets to provide Balancing Services, described in detail in Appendix A). It is envisaged that this ANM scheme will not use a LIFO stack; rather it will utilise a curtailment index that has been included in all ENWL connection agreements since December 2017. The curtailment index does not indicate a likelihood of curtailment by ANM schemes; rather it provides customers with an anticipated maximum level (hours per year) of curtailment – once this level of curtailment is reached, that customer would be moved to the bottom of the curtailment stack. The curtailment in question could be due to ANM, network faults, or a combination of both. The new scheme will cover EHV and HV networks, down to secondary substations. Due to its interface with other automation systems such as the automated fault restoration system and central network systems, the ANM system will have some delay built into it. For example, up to a certain threshold of network capacity, a delay of few minutes might be in place. If power flows exceeded this threshold, the ANM would operate faster. This may offer opportunity for better coordination with NG ESO actions.

3.2.4 NORTHERN POWERGRID

NPg has four ANM schemes in place, varying in complexity and design:

- The simplest arrangement manages a single generator behind a single constraint;

- Seal Sands (two 45/90MVA transformers) manages a number of hydrocarbon generators and industrial load with a combined capacity of circa 280MW and export agreements of circa 190MW. One of the generators is not part of the ANM scheme and provides Balancing Services to NG ESO;
- Blyth manages a transmission network constraint by limiting the export from three generators with a total capacity of 550MW; and
- Driffield manages a constraint at around 120MW across four generators, including biogas and wind generation.

The Seal Sands system includes a likely example of coordination issues arising, where there is a non-curtailable generator in an ANM area that could provide Balancing Services, which the ANM system may counteract (see Test Case 1 in Section 5).

The Blyth system manages a transmission network constraint (limited by NGET transformer installation to 220MVA n-1 / 440MVA total capacity) using generators, including a biomass generator that had a private wire arrangement with an industrial customer. The industrial customer is no longer in place, so all power is exported. The two other generators (windfarms) under the scheme connected while the private wire arrangement was in place, so the LIFO stack first curtails part of the biomass generator, followed by the windfarms, with the remainder of the biomass generator not subject to curtailment. The system is managed by a remote terminal unit (RTU) in a substation and significant fibre optic installation between sites necessary for low latency communication.

The Driffield scheme is managed centrally by NPg's control room. It also uses a LIFO curtailment system but applies a sensitivity factor to determine which generators have the most impact on a given constraint. As the Driffield system is centrally managed, it is scalable for future constraints should the need arise, and NPg expect that system to manage multiple constraints in the future.

NPg's Code of Practice for the application of ANM[34] applies to new connections and the alteration of existing connections where ANM may be necessary to manage the curtailment of the customer's demand or generation to maintain network parameters within limits. The network constraints that NPg will consider managing under an ANM scheme are thermal, reverse power capability, and voltage. The new connections design process must identify the following:

- critical constraint locations;
- connections that contribute to the emergence of a constraint;
- sensitivity factor (SF) between connection export/demand and the severity of a constraint; and
- any existing customers that participate in the ANM scheme and their relationship to constraints.

Sensitivity analysis is conducted to determine the relationship between forecasted generation export and the power flows at each constraint location. One method of determining the sensitivity of each

[34] Code of practice for the application of active network management, NPg, March 2017 https://www.northernpowergrid.com/asset/0/document/3378.pdf

generator towards constraint locations is to begin the analysis with all generators at full rated export, before ramping the study generator down to zero. By observing the corresponding change in power flows at the constraint locations, it is possible to calculate the SF describing the MVA/MW relationship between the generator and each constraint location. For each generator/constraint pairing, an average SF is calculated as the mean of the observed sensitivities as the generator export is ramped from full to zero export. Generators connected in close proximity to each other will have similar sensitivity factors.

For cases where a sensitivity factor of less than 10% is observed, the relationship between the generator and the constraint location is not considered to be significant; therefore that generator is not associated with that constraint and as a result it will not be curtailed due to overload conditions at that constraint location.

3.2.5 UK POWER NETWORKS

UK Power Networks (UKPN) has 17 sites connected to 14 active ANM schemes. The total capacity managed under these schemes is 113.5MW, broken down into 82MW of solar, 21MW of wind and 11MW of gas. There is a further 7.3GW of generation which in non-curtailable but connected within those ANM areas.

Its live schemes are relatively simple in nature, managing single constraints at the GSP level.

However, has rolled out the physical infrastructure required, such as communications systems, to enable an enterprise-wide system, with the timeline for ANM further constraints being managed by ANM driven by constraints materialising.

A further 869MW of capacity has accepted ANM connection offers.

3.2.6 WESTERN POWER DISTRIBUTION

Western Power Distribution (WPD) has wide-ranging ANM schemes in place across 16 GSPs or GSP groups. At the end of 2019, 2.94GW of generation was managed, or had accepted an offer to be managed, under these schemes in aggregate, although the level connected at that stage was 190MW with the vast majority of the total being having an accepted connection offer but not yet connected. This generation is broken down by capacity into 2.05GW of solar PV, 237MW of wind generation and 376MW of gas fired generation, with the remainder made up of battery storage and other technologies. Three of the 16 zones managed constraints on the transmission network, with WPD managing flows at the GSP.

There is a total of 6.94GW non-curtailable generation either connected or accepted in ANM-managed areas (5.26GW connected).

The complexity of schemes ranges from simple schemes managing one constraint, through to complex systems that can theoretically handle any number of constraints. An example of this is WPD's system in Cornwall, which monitors all assets above the 11kV voltage level. Similar schemes are planned in South Devon, Feckenham in the West Midlands, and another location in South Wales.

WPD has used a LIFO stack to determine the order of curtailment across all of its ANM schemes. Actual curtailment levels have been extremely low. Response times for WPD's ANM systems are on the order of minutes, with around 30 seconds for communications and at least a further 30 seconds for the generator to deliver the response.

3.3 KEY DIFFERENCES

One of the most notable differences between different DNOs is the speed of response of ANM schemes. Some can instigate a sub-second response from generators; others seek a response within around five minutes.

Those systems which seek a slower response are typically curtailing "pre-event", where an "event" may be a network fault or other outage, or any other low probability occurrence impacting power flows on the network. That is, the curtailment applied by the ANM is sufficient to ensure that, should a network fault occur, network assets will not be overloaded. For example, if the constraint is at a two-transformer substation, the ANM scheme will ensure that power flows through that substation are at most half of its rating so that, should either transformer fail, the load can be managed by the remaining live transformer without breaching its operational limit.

By contrast, those with a faster response can curtail "post-event" by responding to faults as they occur.

So, in broad terms, there is a trade-off between:

- The extent to which the ANM scheme can maximise use of network assets, which is best achieved by a very fast response; and
- The cost of hardware and software for the system, which is much lower for slower systems which can rely on standard hardware at the point of connection.

There is also a key interaction with Operational Tripping Schemes (OTS) which operate post-event to rapidly trip generation under certain fault conditions. The fastest ANM schemes are able to effectively act as both ANM and OTS while slower response ANM schemes work alongside OTS, with OTS acting as the fail-safe. For example, should multiple faults occur, OTS will rapidly trip generators to secure the network, while ANM manages power flows in all other circumstances.

3.4 GEMS

GEMS, as introduced in section 2.1.2, will provide a similar function to DNO ANM schemes on the transmission network. The system remains in development.

A key differentiator will be that GEMS will operate on a price stack, with generators compensated for curtailment. DNO ANM schemes do not directly compensate generators for curtailment. It is also different to DNO ANM schemes in that NG ESO will have complete visibility over the system.

GEMS will also interface with SPEN ANM systems, and this will be the case in South West Scotland where SPEN is taking forward its Dumfries and Galloway project. Details of communications between the SPEN ANM system and GEMS are to be confirmed, but coordination here will allow GEMS to factor ANM action into its curtailment logic.

3.5 INTERNATIONAL COMPARATORS

There are relatively few international comparators in which generation requires active curtailment due to network overloading. There are, however, some similar issues to those described in this report in other countries.

3.5.1 AUSTRALIA

In Australia, all generators above 30MW are obliged to register with the market operator and submit bids and offers which the market operator uses to balance supply and demand and manage transmission constraints (akin to the BM in GB).

Small scale generation (primarily rooftop solar) is a significant driver of distribution constraints, more so than unlicensed generators (most generators <30MW). Residential customers have a 5kW export “allowance” which many use – there is as much as 80% rooftop PV penetration in some residential areas.

As it currently stands, there is no active control of these PV systems by distribution network service providers (DNSPs). DNSPs apply static restriction levels on the maximum allowable exports from rooftop PV in areas where there are technical issues (such as fluctuating voltage levels). This level is commonly set at 5kW, but in some cases this is reduced to 2.5kW or even 0kW. These limits are usually applied on a ‘first come first served’ basis, similar to the LIFO system used in many GB ANM schemes, which raises issues of inequity. Automatic curtailment to enforce these limits is primarily carried out through automatic inverter controls, which curtail PV generation as a result of voltage levels on the feeders exceeding limits. This is most common during the middle of the day when rooftop PV is exporting. This automatic curtailment is similar to ANM schemes used by DNOs in GB.

This is the closest parallel for coordination issues with GB ANM schemes – i.e. how curtailment of small-scale generation by the distribution provider fits with the market operator’s actions.

3.5.1 DENMARK

Denmark has a target of generating 100% of electricity from renewable sources by 2050. Much of this is likely to be met through wind power and Denmark has needed to adapt the management of its networks to accommodate the high levels of wind generation. As on other grids with high shares of renewable energy like Germany, Spain and California, Energinet.dk has incorporated advanced day-ahead weather forecasting into generation dispatch and grid control. Weather forecasting has helped Denmark integrate and balance renewables by making them highly predictable. Additionally, strong interconnections to neighbouring systems and well-functioning international electricity markets, including negative price signals to incentivise wind and other generation to reduce output during over-generation help to support this high level of wind integration. All wind power is traded in the markets (day-ahead and intraday power markets), either by production balancing actors or by the Danish Transmission System Operator (TSO).

Curtailment arrangements have been put in place to ensure that wind farms do not produce too much power and exceed network operation limits. Due to the large amount of wind on the Danish system, when wind speeds are high the level export on the network can be too high. For example, on 9 July 2015, unusually strong wind conditions resulted in 116% of national electricity consumption being produced by wind farms and at 3 am the next morning wind production exceeded 140% of demand. This new regulatory scheme was put into place to curtail offshore wind, and generators do not receive any financial compensation for this curtailment. Emergency curtailment is rare in Denmark due to the large interconnection capacities and the introduction of negative prices has contributed to reduced supply from conventional generation in the relevant hours.

This regime differs from ANM as wind farms are curtailed on the basis of forecast outputs rather than in real time, but it demonstrates a successful approach in agreeing curtailment between network operators and generators and shows how the introduction of trading markets specifically for wind power have allowed high levels of wind integration.

3.5.2 GERMANY

In Germany, DER has been actively managed against transmission and distribution constraints under an arrangement called Einsman, which stands for Einspeisemanagement (“infeed management”). It is defined in German federal law and allows for curtailment when specific areas of the network are constrained. It started in 2009 for large connections and has since been extended down to 100kW. Each connection is established through a device (e.g. RTU) at that the interface with the DER control system. Larger DERs connect into the DSO's SCADA infrastructure while the smaller DERs are managed using ripple control. There is a large amount of Einsman-connected DER across Germany.

Einsman spans both across the transmission and distribution networks to support constraint management. The TSO can send signals to the DSO to reduce the output of participating DER under Einsman as can the DSO against its own constraints. However, most curtailments to date have been observed to be due to transmission constraints. This is likely because transmission constraints are often reached before downstream distribution constraints so mask distribution network issues which would arise if the TSO were to allow the DER to run unconstrained.

The relationship of this to the GB BM is limited due to a ‘must take’ arrangement and a set of curtailment rules based on technology type and the various federal laws, rather than BM type participation. Curtailment is done on a look ahead basis at the transmission and distribution networks using the Einsman systems. Both the TSO and the DSO can issue constraint instructions.

There is a set amount or curtailment that the TSO and DSOs can enact each year before they must make physical network reinforcements (known as the 3% rule), so the use of the Einsman scheme is driven by deferral of that reinforcement.

With increasing adoption of renewables and distributed generation, legislators in Germany have revised the regulations (NABEG 2.0) that require the shutdown of generating units in the event of network constraints.

4 RISKS OF UNCOORDINATED ANM SCHEMES

In order to develop the Test Cases which will be used for the remainder of the project, we have first assessed the risks that arise when ANM schemes are not coordinated with Balancing Services procurement and instruction. There is broad acknowledgement that ANM schemes that are uncoordinated with procurement of Balancing Services may lead to poor outcomes for both security of supply and cost to consumers.

The risks can be broadly categorised into those that arise in respect of Balancing Services procurement from ANM generators and non-curtailable generators in an ANM area respectively.

4.1 ANM GENERATORS

4.1.1 RISK OF NON-DELIVERY

ANM generators risk defaulting in respect of their provision of Balancing Services due to ANM curtailment.

For example, an ANM generator that has an Offer accepted in the BM is required to increase output in line with the ramping profile detailed in its BM Offer. If the ANM constraint is reached before that generator has ramped to the full output required in its BM Offer, that generator is likely to be subject to curtailment and so will be unable to deliver its Offer.

Similarly, an ANM generator with a STOR contract will be unable to increase its output in line with that contract if it is subject to curtailment by the ANM scheme at the time at which it is called.

The BM is clear that the risk of non-delivery sits with the generator submitting the BM Offer – in this case the ANM generator – and so it will be exposed to the costs of non-delivery. There are penalty schemes within all Balancing Services that would penalise the generator for not providing the service as outlined in the contract terms.

However, non-delivery penalty risk may not be sufficient to dissuade the generator from Balancing Services participation, giving rise to a situation in which the generator in question may be contracted to provide but does not deliver the required service to NG ESO, creating a risk to security of supply.

4.1.2 RISK OF UNNECESSARY RESTRICTIONS

One way in which this situation described in Section 4.1.1 could be resolved is to block participation of ANM generators in Balancing Services, as is the case with the recently developed ODFM service, or to ensure that non-delivery penalties are sufficiently strong to dissuade ANM generators from participation. The restrictions in place are often ambiguous, with little distinction between ANM generators and non-curtailable generators in ANM areas.

This ensures that ANM schemes will not prevent delivery of Balancing Services obligations. But curtailment by ANM systems is typically only required for a relatively small proportion of the year. A blanket barrier to Balancing Services provision risks sub-optimal outcomes by unnecessarily reducing

Balancing Services market liquidity at times when the ANM system is not active. Ultimately, lower liquidity is likely to increase the cost of Balancing Services procurement, borne by consumers.

4.2 NON-CURTAILABLE GENERATORS IN AN ANM AREA

4.2.1 RISK OF COUNTERACTION

Non-curtailable generators can participate in Balancing Services without risk of defaulting on service provision due to ANM curtailment. But in some instances, curtailment actions taken by an ANM system will counteract such actions, resulting in NG ESO paying for a service but not seeing any net change in power flow. This is both costly for consumers and a risk to security of supply

For example, a non-curtailable generator which has an Offer accepted in the BM is required to increase output in line with the ramping profile detailed in its BM Offer. It is non-curtailable, so the ANM system will always allow it to do so. But if the ANM constraint had already been reached prior to that Offer being accepted, the ANM system will be forced to curtail another generator to avoid the constraint limit being breached.

This is shown in Figure 4-1, where both Generator 1 and Generator 2 are behind an ANM constraint but only Generator 2 is ANM controlled.

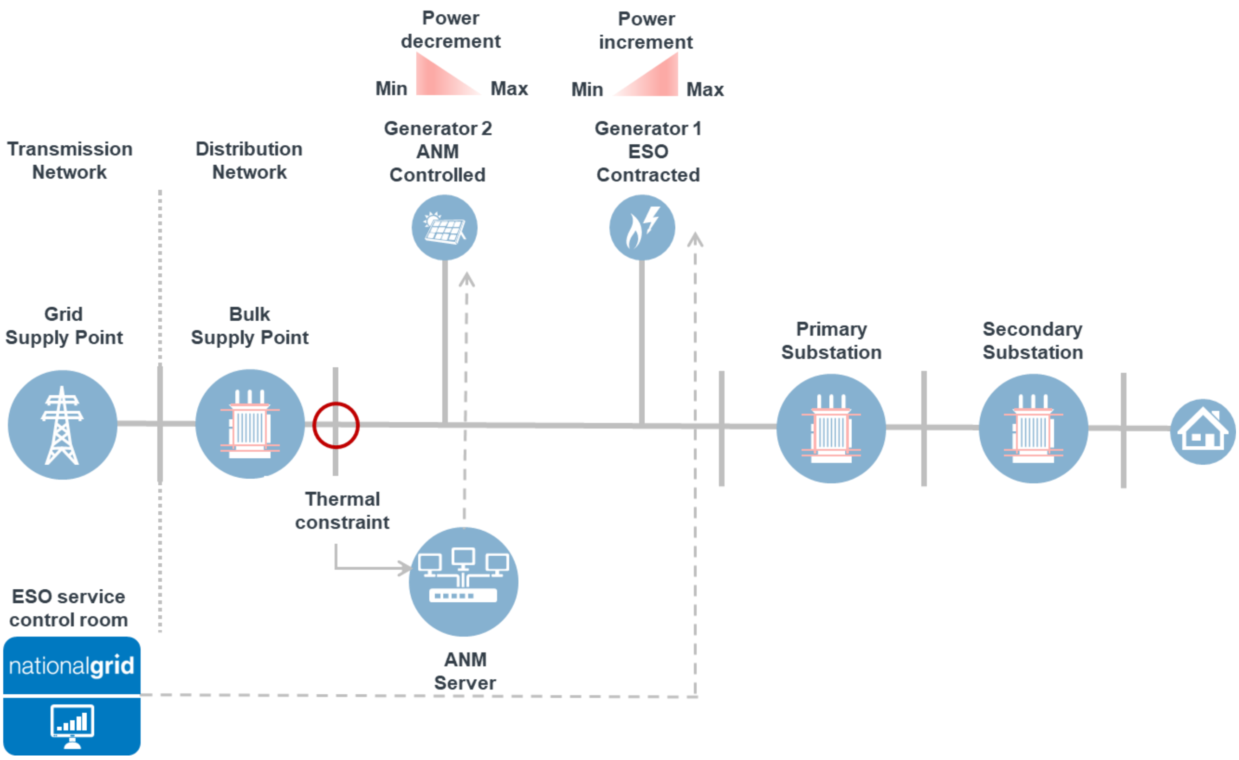

Figure 4-1: Example schematic of parties and interactions

Generator 1 ramps output by 1MW, but in response the ANM system takes an equal and opposite action by curtailing Generator 2, reducing output by 1MW.

Figure 4-2 illustrates the cumulative effect these actions have on net generation, showing that the actions of Generator 2 mean that net generation remains the same before and after the Balancing Service request.

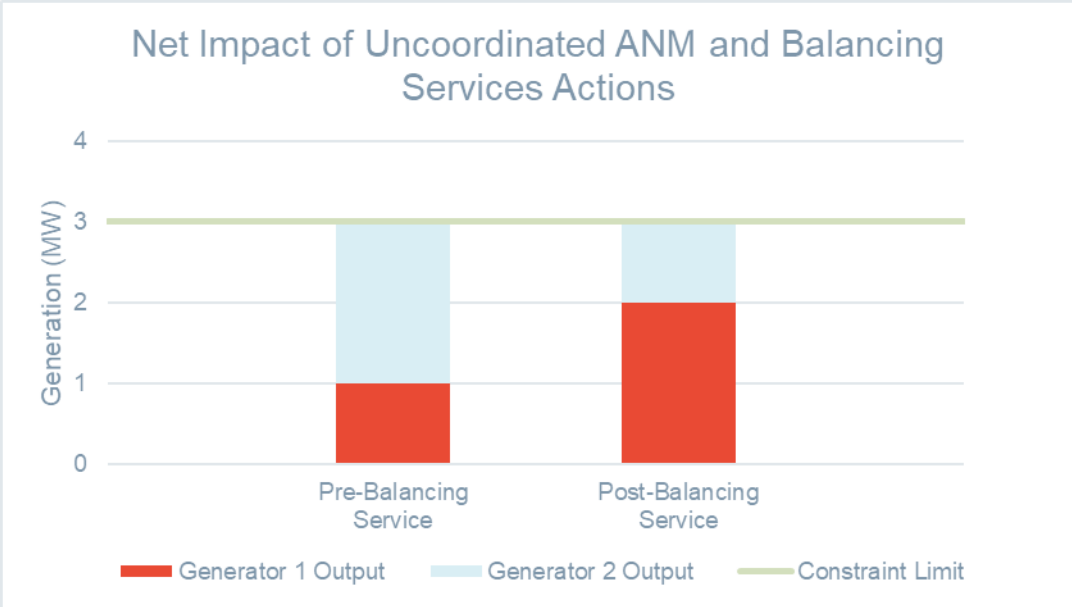

Figure 4-2: Cumulative effect of the actions of Generator 1 and Generator 2 on net generation

In this situation, NG ESO has procured a service from Generator 1 which Generator 1 has delivered, but there is no net system benefit to the wider system above the ANM constraint limit. As a result, NG ESO may be forced to accept another BM Offer, unnecessarily increasing costs to consumers.

4.2.2 RISK OF OVER-REACTION

In some instances, a generator ramping output to provide a Balancing Service may do so faster than an ANM generator can ramp down. In this case, the ANM system may be forced to trip the ANM generator entirely and allow it to come back on the system when it is safe to do so.

Using the example in Section 4.2.1, if Generator 1 ramps up faster than Generator 2 can ramp down, the ANM system may be forced to trip Generator 2, reducing its output to zero. Figure 4-3 illustrates the cumulative effect these actions have on net generation, showing that the actions of Generator 2 mean that net generation drops after the Balancing Service request.

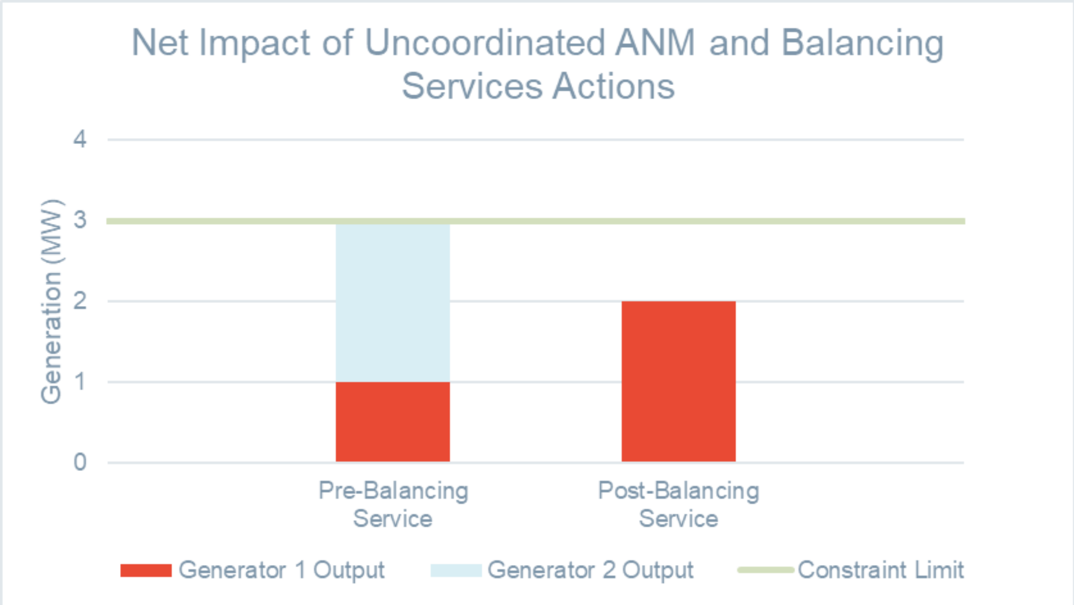

Figure 4-3: Cumulative effect of the actions of Generator 1 and Generator 2 on net generation

So, the curtailment may in fact exceed the increase in generation called by NG ESO, leading to NG ESO seeing an overall **reduction** in generation despite its objective in dispatching the non-curtailable generation being to **increase** generation. This is a clear risk to security of supply.

The Seal Sands example on the NPg network presents this risk. There is a combination of non-curtailable generation and ANM generation behind the constraint with a non-curtailable gas generator able to ramp up faster than the ANM generators can ramp down, in which case the ANM system will trip the ANM generators entirely.

5 DEFINITION OF TEST CASES

This section presents the network Test Cases that have been developed as a result of the review and analysis of the relevant literature that has been conducted, as well as internal discussions and technical workshops with the project team, the NG ESO and WPD teams, and other stakeholders through bilateral discussion or the Advisory Group. Table 5-1 summaries the Test Cases, which are set out in detail in this section.

The description of each Test Case sets out the potential conflicts between the provision of Balancing Services and ANM control systems and includes an example and diagrams where appropriate. Furthermore, the network and customer benefits associated with better coordination between ANM systems and Balancing Services markets are explored within each Test Case.

Table 5-1: 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		Reactive power absorption through tap stagger (through CLASS) 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

5.1 TEST CASE 1

Test Case 1 is split into three sub examples, 1A, 1B and 1C involving distribution or transmission ANM systems counteracting the provision of a Balancing Service to NG ESO by DERs or transmission connected energy resources (i.e. generation / demand), respectively. In these Test Cases, the conflict is caused when an ANM system increases or decreases the export limit of ANM generators under its control in response to the dispatch of a Balancing Service from a non-curtailable generator in the ANM area. The three Test Cases are described further below.

5.1.1 TEST CASE 1A – ANM GENERATOR COUNTERACTS INCREMENTING SERVICE ACTION FROM A NON-CURTAILABLE GENERATOR IN AN ANM AREA

5.1.1.1 Description

This Test Case involves the situation in which a non-curtailable generator in an ANM area provides Balancing Services to NG ESO. Test Case 1A involves the generator performing an incrementing service. Similarly, this case also applies to a demand customer reducing demand through DSR. Figure 5-1 shows an example of the parties involved and the interactions that take place in test case 1A.

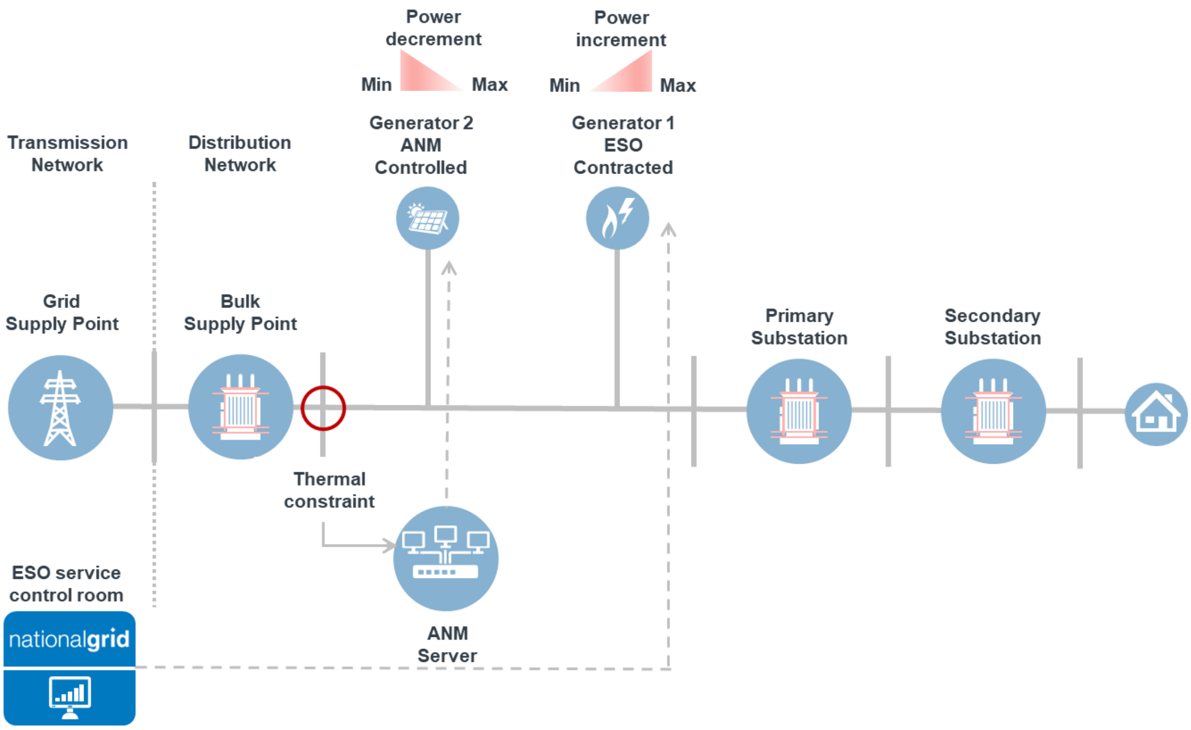

Figure 5-1: Example schematic of the parties and interactions involved in Test Case 1A

In Test Case 1A, we consider a situation in which a non-curtailable generator in an ANM area (Generator 1) is called upon to provide a balancing service that increments whilst the ANM scheme is active (i.e. output from ANM generators is being constrained) or the ANM scheme is not active but the network is at capacity and so the ANM scheme will be triggered if generation increases. In practice, this could represent a situation where the frequency of the electricity system may have dropped below the acceptable limit and the NG ESO has dispatched a non-curtailable generator in an ANM area to provide a reserve support service.

Generator 1 increases its export to fulfil the requirements of the Balancing Service. This action raises the generation export on the network above the constraint limit imposed by the local ANM system. In response, the ANM system will send a signal to an ANM generator (in this case Generator 2) to reduce its export.

Generator 2 then reduces its output to keep the network within its required export capacity limit. As a consequence, the desired effect from the provision of the Balancing Service has been negated. NG ESO has paid Generator 1 for a service but has seen no change in the condition of the network since this was counteracted by Generator 2 via the ANM system.

Figure 4-2 illustrates the cumulative effect these actions have on net generation, showing that the actions of the ANM scheme in curtailing Generator 2 mean that net generation remains the same before and after the Balancing Service was delivered by Generator 1. Figure 4-2 demonstrates a case where the provision of the Balancing Service is fully negated (i.e. null net effect) due to the ANM scheme; in practice, the Balancing Service may only be partially counteracted.

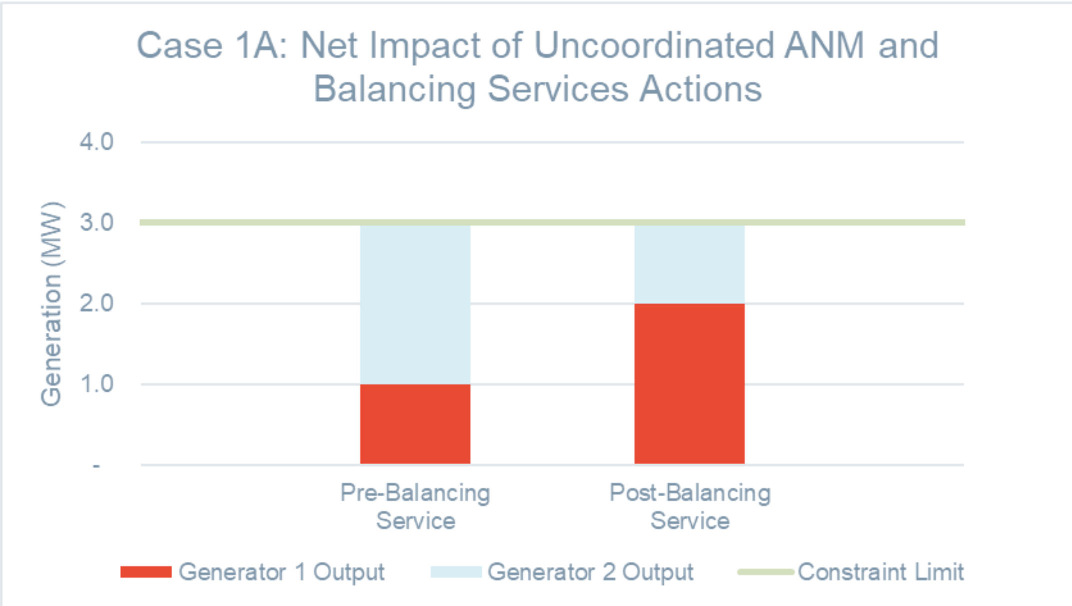

Figure 5-2: Cumulative effect of the actions of Generator 1 and Generator 2 on net generation before and after the balancing service request in Test Case 1A

This would apply to services such as frequency response and reserve services when the frequency of the system has dropped below the acceptable limit, or acceptance of a BM Offer. A detailed description of these services and their requirements can be found in section 2.3.

For the fastest ANM responses, it is likely that the ANM will curtail Generator 2 at almost exactly the rate at which Generator 1 ramps its output, while slower response systems may result in net generation increasing for a period of time before being counteracted.

Alternatively, NG ESO may instruct demand turn down. If this service is procured from a demand customer located within an area of the network with an ANM scheme, the same conflict will arise. With less demand on the system, the ANM scheme will send a signal to further constrain ANM generator(s). Again, the service effect will be negated.

This may pose a risk to security of supply as the Balancing Service that was needed has not been implemented for the required duration, meaning the likelihood that the system will go outside of its operational limits will increase. NG ESO will then need to dispatch another Balancing Service provider, increasing the cost of balancing the system, which is ultimately passed onto the consumer through Balancing Use of System (BSUoS) charges.

5.1.2 TEST CASE 1B – ANM GENERATOR COUNTERACTS DECREMENTING SERVICE ACTION FROM A NON-CURTAILABLE GENERATOR IN AN ANM AREA

5.1.2.1 Description

Test Case 1B is similar to Test Case 1A but it concerns a Balancing Service which decrements, such as a Balancing Mechanism Bid acceptance or ODFM. In this case, Generator 1, which is a non-curtailable generator in an ANM area, is called upon to provide a Balancing Service that decrements whilst the ANM scheme is active (i.e. output from other ANM generators is being constrained). Generator 1 decreases its export to fulfil the requirements of the service. In response to the Balancing Service effect, the ANM system may send a signal to Generator 2 enabling it to increase its export as the constraint on the network has lessened.

As a consequence, the Balancing Service effect may be negated. Therefore, NG ESO pays Generator 1 for a Balancing Service but there is no change in the condition of the network since this was counteracted by Generator 2 via the ANM system.

Figure 5-3 shows an example schematic for the setup of Test Case 1B and Figure 5-4 illustrates the cumulative effect these actions have on the net generation, showing that the actions of Generator 2 causes the net generation to remain unchanged before and after the balancing service request was delivered by Generator 1.

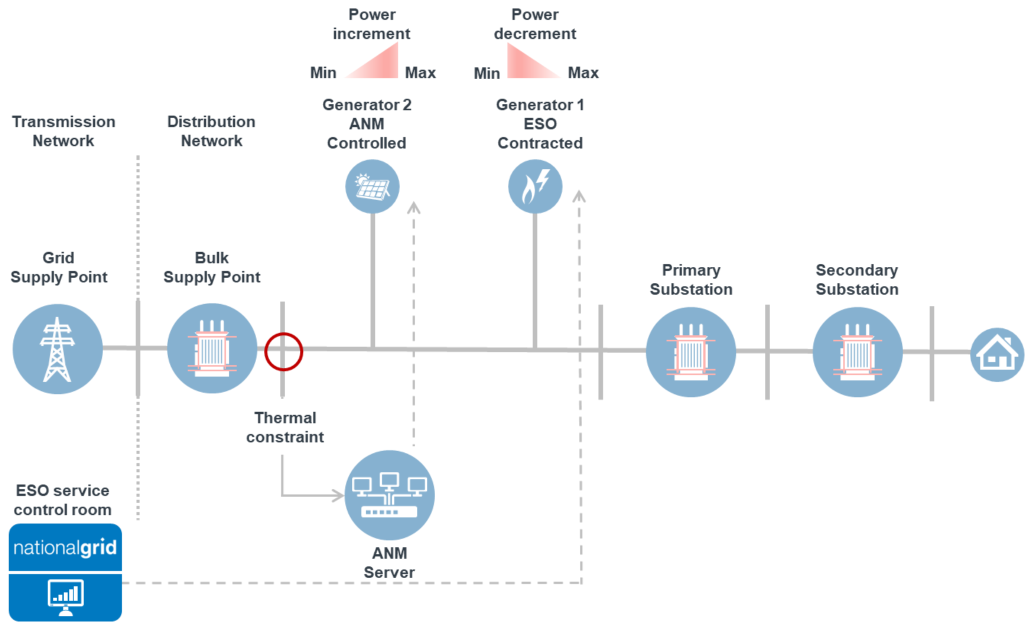

Figure 5-3: Example schematic of the parties and interactions involved in Test Case 1B

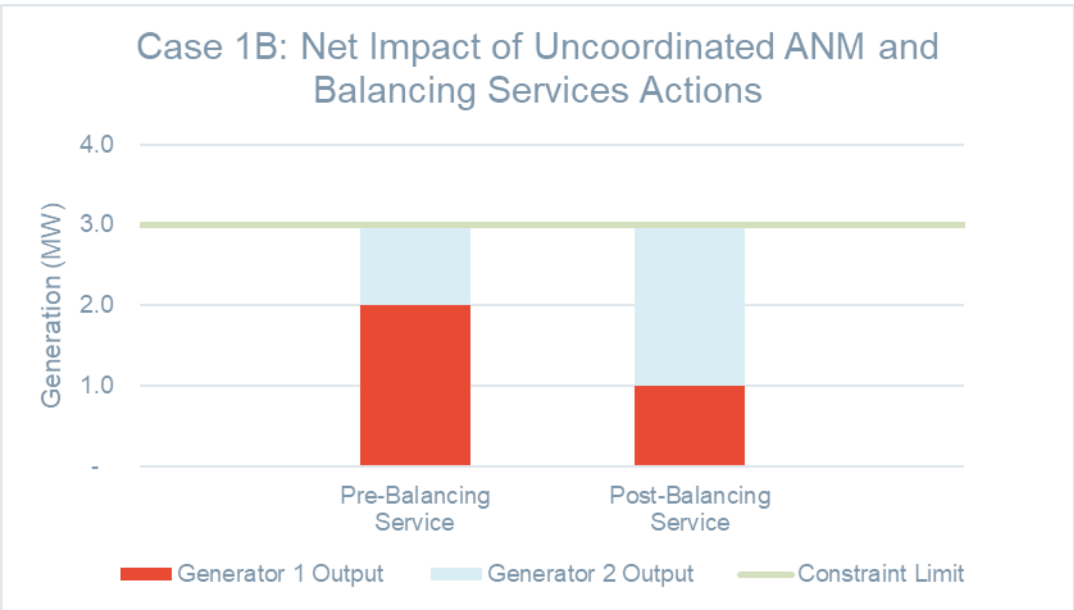

Figure 5-4: Cumulative effect of the actions of Generator 1 and Generator 2 on net generation before and after the balancing service request in Test Case 1B

This would apply to Balancing Services such as frequency response and reserve services when the frequency of the system has increased above the acceptable limit, or acceptance of a BM Bid. A detailed description of these services and their requirements can be found in Section 2.3.

Alternatively, NG ESO may dispatch additional demand through the Demand Turn Up service to ease system conditions, for example, when high levels of solar generation are present on the system. The day service window for Demand Turn Up was selected to coincide with periods of low demand and maximum output from solar generation, which is also the time when ANM schemes are most likely to be operating. The demand increase instructed by the balancing service could be counteracted by the generation increase allowed by an ANM scheme in an export-constrained distribution network. If a Demand Turn Up service provider was located within an export-constrained network with ANM, the increase in local power consumption would see greater capacity for generation and release the commensurate capacity to the generation. This would negate the Demand Turn Up instruction.

The issues around system security and the cost of services that are present in Test Case 1A apply here.

5.1.2.2 Benefits of better coordination

Coordination of ANM and Balancing Services for network test cases 1A and 1B will make NG ESO balancing operations more efficient by ensuring that NG ESO, and therefore consumers, do not pay for a service without material and long-lasting benefit to the network.

5.1.3 TEST CASE 1C –GEMS GENERATOR COUNTERACTS SERVICE ACTION FROM A NON-CURTAILABLE GENERATOR IN A GEMS AREA

5.1.3.1 Description

Test Case 1C considers the conflicts that may arise between GEMS and wider procurement of Balancing Services by NG ESO. GEMS will allow generators to take part in the BM by agreeing for their systems to ramp up or down to help balance the network based on a ‘bids and offers’ framework. Transmission connected generators will have their own BMU so NG ESO has sight of where the generators are connected and has visibility of them with respect to transmission network constraints. GEMS will create network headroom to allow services to be procured by constraining generators. If this is action is not appropriately coordinated with the wider Balancing Services then the potential exists for conflicts between GEMS schemes and Balancing Services markets to arise.

In this context, Test Case 1C is similar in principle to that of Test Case 1A and 1B. As with generation connected into the distribution network, not all transmission generation will be under the control of GEMS. As such, a non-curtailable generator in a GEMS area may be dispatched to provide a Balancing Service, and this action may be counteracted by the constraining action of GEMS, whether it is an incrementing service or a decrementing service that is being procured.

This may pose a risk to security of supply as the balancing action that was needed has not had the desired net impact on the network that would have been expected. This risk may cause the network to operate outside of its statutory limits. To counteract this, NG ESO will then need to dispatch another service provider, increasing the cost of balancing the system, which is ultimately passed onto the consumer. However again, this additional service provider may also be counteracted by the GEMS system decreasing the security of supply even further.

Figure 5-5 shows an example schematic illustrating the parties and interactions involved in Test Case C and Figure 5-6 shows how the actions of Generators 1 and 2 results in no change in net generation before and after the balancing service request.

In contrast, it should be noted that GEMS could be designed to overlay the ANM technology it will use on top of existing BM tools and the Platform for Ancillary Services (PAS) to achieve streamlined coordination therefore resolving any potential conflicts. This coordination mechanism will have to be capable of coping with a set of dynamically changing variables, whereas distribution ANM schemes typically focus on managing access to networks based on connection queues. It is likely that there will be an additional cost to dispatching a generator for a balancing service, as generators will be paid for constraining.

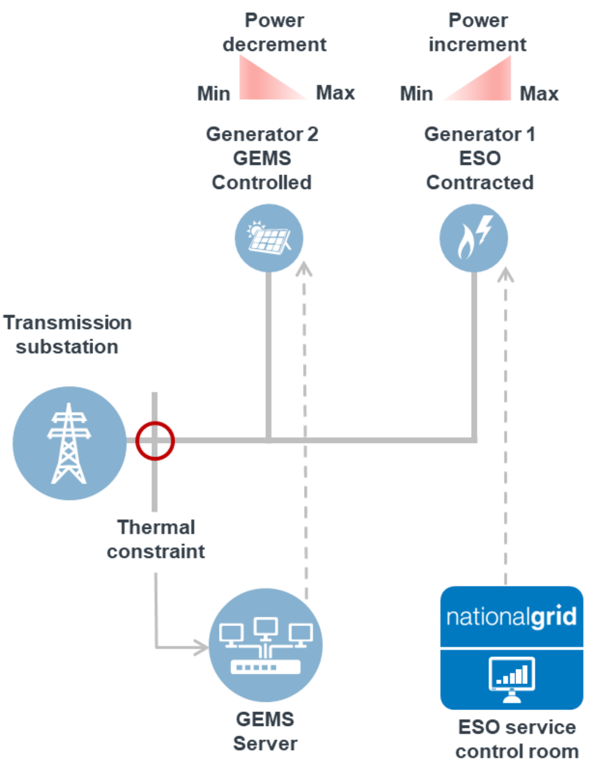

Figure 5-5: Example schematic of the parties and interactions involved in Test Case 1C

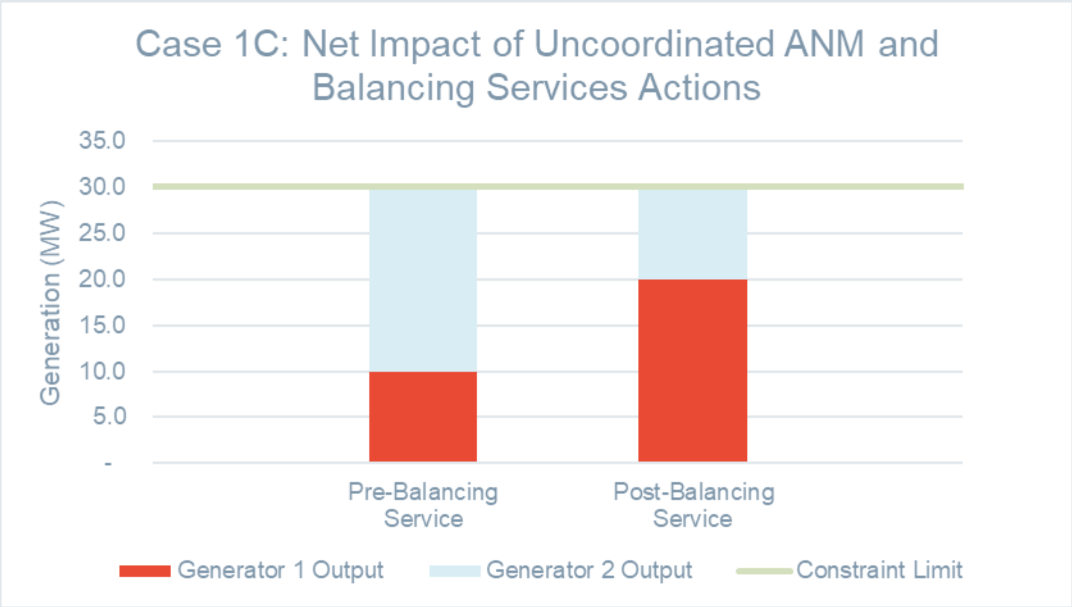

Figure 5-6: Cumulative effect of the actions of Generator 1 and Generator 2 on net generation before and after the balancing service request in Test Case 1C

5.1.3.2 Benefits

Coordination of GEMS and Balancing Services will lead to the following benefits:

- Better coordination will ensure that GEMS can improve upon the existing BM tools and ensure that the system is balanced efficiently, and renewable resources can gain access to the network and be fully utilised;
- Coordination between generators with a firm connection in the area and the GEMS will ensure that the required balancing effect is delivered at the lowest cost to consumers; and
- Improved coordination will also mitigate against the risk that the stability and security of the network will be compromised by competing and uncoordinated BM systems.

5.2 TEST CASE 2

The procurement of Balancing Services by NG ESO from the CLASS system can potentially create conflicts with any ANM control systems that are in operation within the vicinity of the CLASS primary substation. ENWL is currently the only DNO that provides Balancing Services to NG ESO from CLASS. This may change depending on Ofgem's position going forward.

To date, the potential conflicts and synergies described below have not reduced the effectiveness of the CLASS system. However, the frequency of these conflicts is likely to increase as the penetration of ANM generation increases over time and NG ESO's requirement for Balancing Services increases.

Figure 5-7 below illustrates a CLASS enabled primary substation and the ANM generation that may be impacted by its operation. The potential conflicts and synergies between a CLASS substation and an ANM system are described with reference to Figure 5-7. This includes a description of each potential control action from the CLASS system and the possible above uncoordinated response from ANM generators.

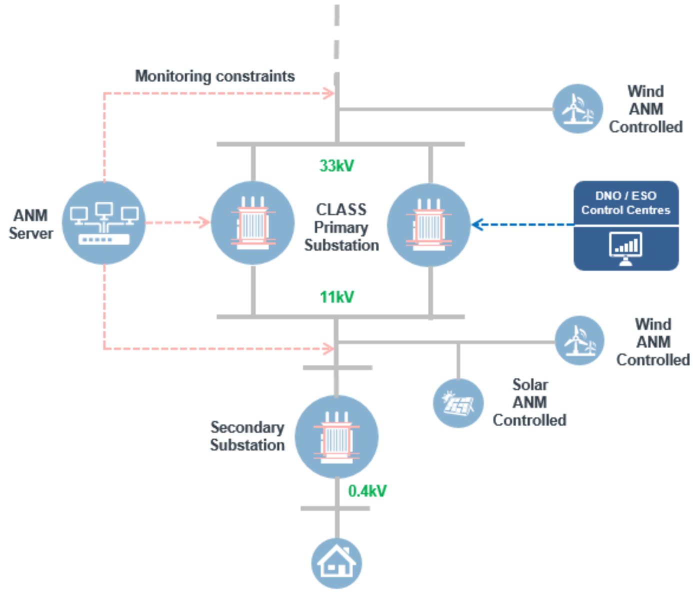

Figure 5-7: Schematic showing an example arrangement of a CLASS and ANM system on the distribution network

5.2.1 TEST CASE 2A – DEMAND REDUCTION THROUGH LOWERING OF TAP POSITION

In response to the detection of an under-frequency threshold (49.7Hz) by the CLASS AVC relays or at the request of NG ESO, the CLASS system lowers the tap position of both primary transformers shown in Figure 5-7. The subsequent reduction in voltage creates an immediate reduction in network demand through the principles of conservation voltage reduction (CVR). This is a service provided to NG ESO to help mitigate low frequency or lack of generation during periods of high demand. In response, ANM systems can both counteract or support this reduction in demand depending on whether the ANM generation is constrained by a thermal or voltage limit.

Firstly, if an ANM system is present at the primary substation and is active at this time (i.e. ANM is constraining the power export level of generators in the area), the reduction in demand from network customers due to the lower network voltage will in turn reduce the thermal capacity available within ANM control areas for generation. Previously, the higher network demand reduced the export requirements of the local generation therefore reducing export constraints. Without this demand, the output from the ANM controlled generation becomes restricted further.

In response, the ANM system will further curtail any ANM generation connected beneath the primary transformers on the 11kV network as illustrated in Figure 5-7. This reduction in generation output will counteract the reduction in demand caused by the initial operation of the CLASS system.

Consequently, an uncoordinated response by ANM control systems to this action of the CLASS system has the potential to counteract the initial objective and reduce the effectiveness of the CLASS system to provide secondary frequency response to NG ESO.

This is illustrated within Figure 5-8 below where the net demand on the primary transformers remains the same despite a decrease in customer demand cause by the CLASS system.

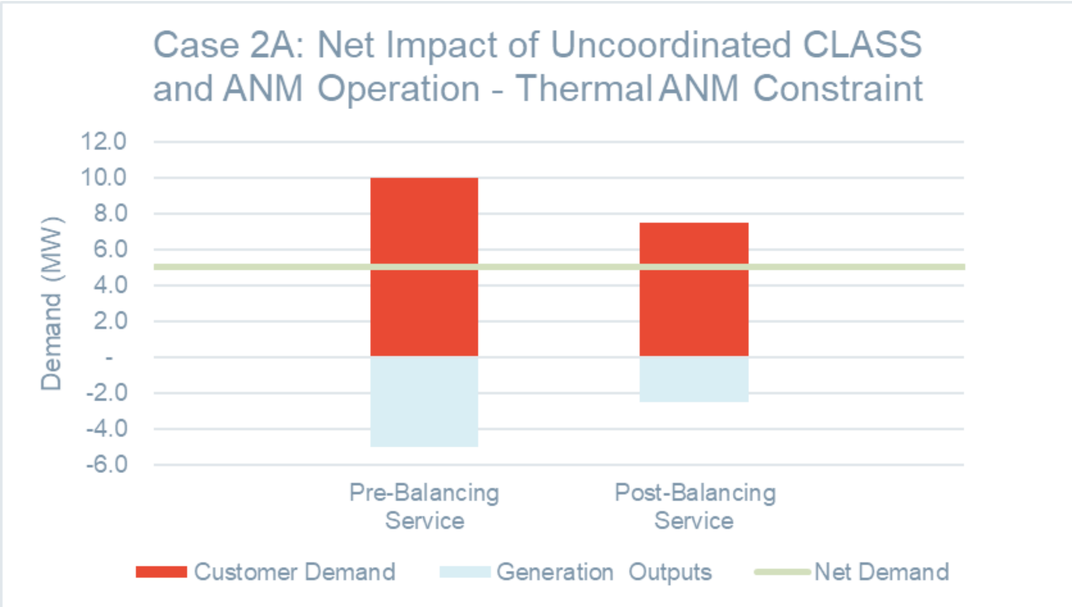

Figure 5-8: Cumulative effect of the actions of the CLASS and ANM systems on net demand before and after the balancing service request in Test Case 2A - Thermal ANM Constraint

Secondly, this action by the CLASS system can also create synergies between the ANM systems and the secondary frequency response service that is being provided to NG ESO by the CLASS system. If the ANM controlled generators are constrained by voltage, lowering the tap position of the primary transformers could in fact release additional capacity for further ANM generation output. This is the opposite effect to the thermal ANM constraint previously described.

In this case the reduction in 11kV voltage will both reduce the demand from customer loads and increase the output from DER. This combined effect will further reduce the total demand on the primary transformer and increase the scale of the service provided to NG ESO. This synergy is illustrated in Figure 5-9.

Whilst this interaction between CLASS systems and ANM increases the scale of the secondary frequency response service provided to the NG ESO, it is still important that DNOs can predict and account for the cumulative effect this synergy may have. This will ensure DNOs report their availability accurately and NG ESO do not inadvertently over-correct the frequency of the network when providing this service.

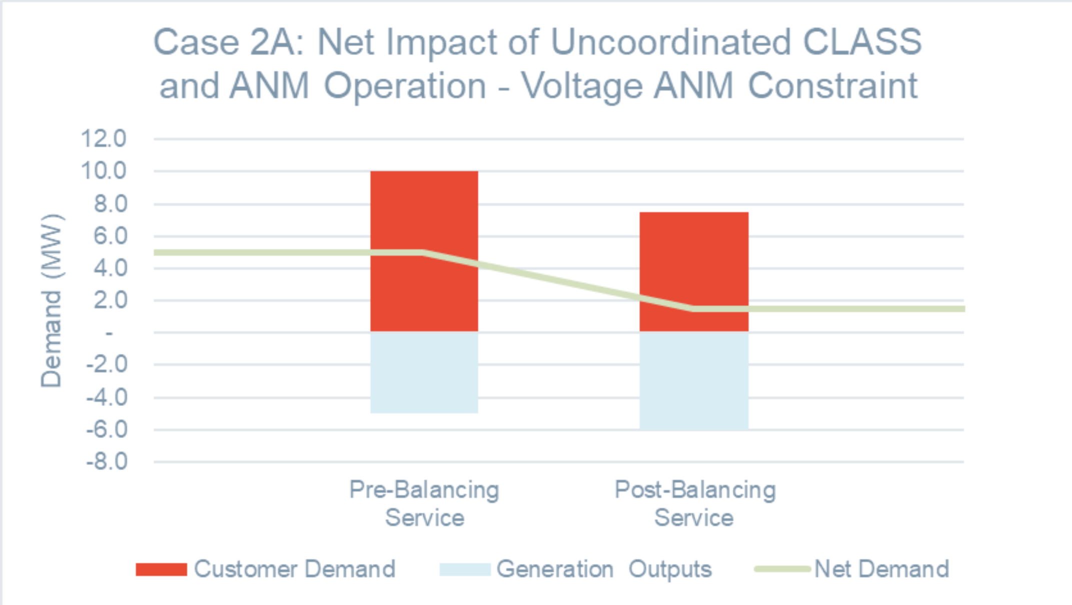

Figure 5-9: Cumulative effect of the actions of CLASS and ANM systems on net demand before and after the balancing service request in Test 2A - ANM Voltage Constraint

5.2.2 TEST CASE 2B – DEMAND BOOST THROUGH INCREASE IN TAP POSITION

In response to an over-frequency threshold detection by the CLASS AVC relays or at the request of NG ESO, the CLASS system increases the tap position of both primary transformers. This increase in voltage causes an increase in network demand. This is a service that can be provided to the NG ESO to help mitigate high frequency or excess generation during low demand periods. Whilst ENWL do not currently offer this service to NG ESO, the capability exists within the CLASS system and it may be offered in the future if the need for this service increases or other DNOs adopt CLASS.

The increase in network demand caused by increasing the voltage on the network could also increase the export capacity available to an ANM control system and the generators under its control if:

- An ANM system is present at the primary substation;
- That ANM system is active at the time of this action; and
- The ANM system is addressing thermal constraints.

In response, an ANM system could decrease the level of curtailment and allow the generators it controls to increase their export. This increase in output will then offset the higher demand caused by the initial CLASS tap changer action and reduce the effectiveness of the frequency service provided to NG ESO.

The cumulative effect of this is illustrated in Figure 5-10 below where the net demand stays the same despite an increase in customer demand after the CLASS system taps up the primary transformers.

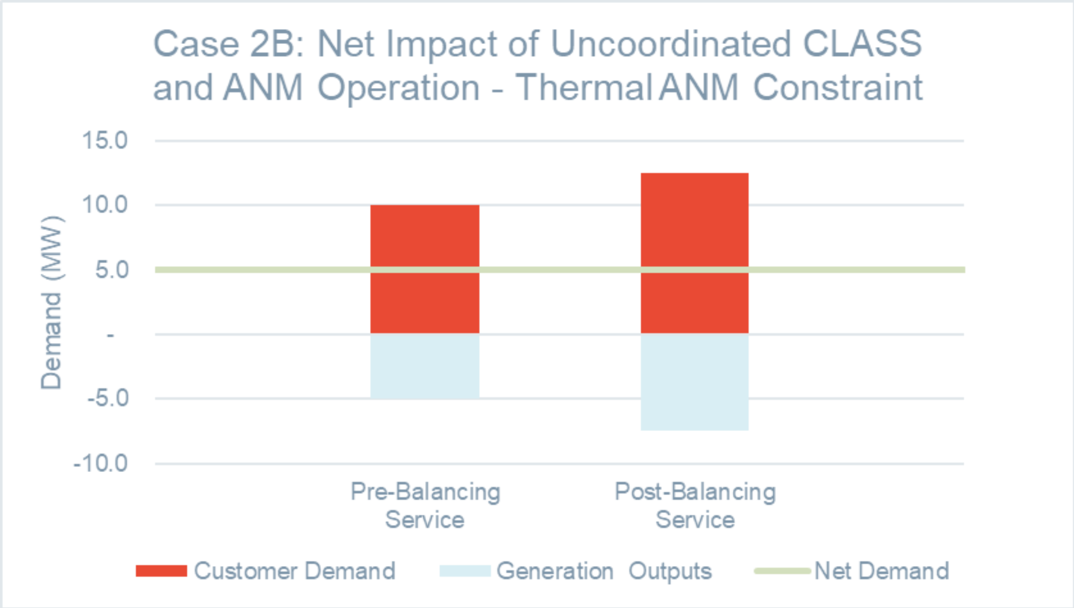

Figure 5-10: Cumulative effect of the actions of the CLASS and ANM systems on net demand before and after the balancing service request in Test Case 2B - Thermal ANM Constraint

This action by the CLASS system can also create synergies between the ANM systems and the Balancing Service that is being provided to NG ESO by the CLASS system to help mitigate high frequency or excess generation during low demand periods. Raising the tap position of the primary transformers will increase the network voltage and consequently the demand from network customers. However, this increase in voltage could in turn create new local voltage constraint and reduce the networks capacity for generation output. In response, an ANM control system would instruct generators to ramp down to maintain operation within the voltage statutory limits. This reduction in local generation will in turn increase the net demand associated with that portion of the distribution network. This combined effect will further increase the total demand on the primary transformer and increase the scale of the service provided to NG ESO. This synergy is illustrated in Figure 5-11.

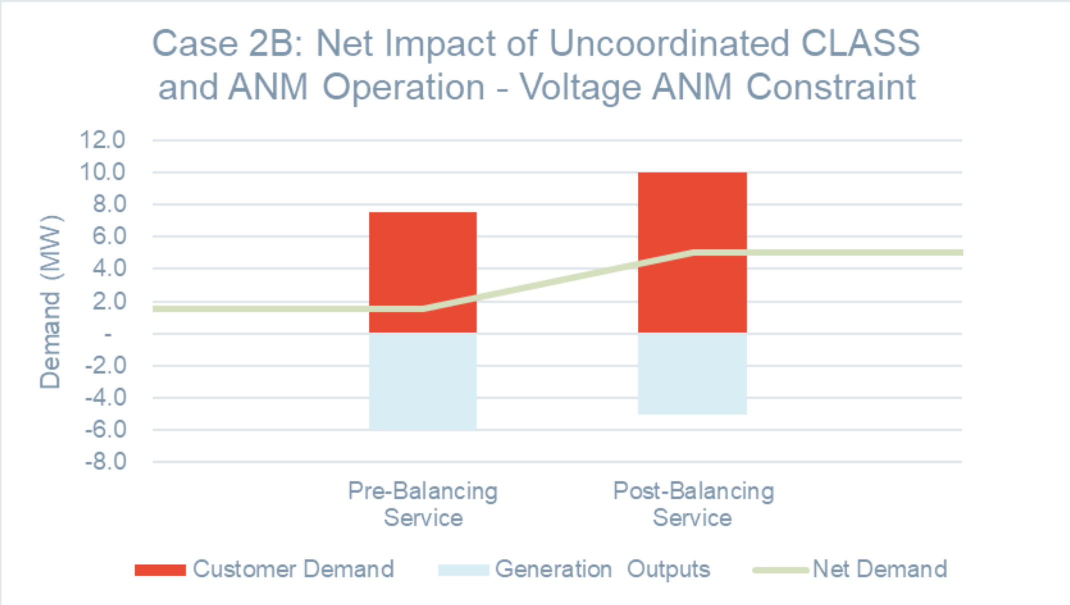

Figure 5-11: Cumulative effect of the actions of CLASS and ANM systems on net demand before and after the balancing service request in Test 2B - ANM Voltage Constraint

5.2.3 TEST CASE 2C – TAP STAGGER TO ABSORB REACTIVE POWER

In response to a reactive power compensation service request from NG ESO, the CLASS tap staggering functionality creates circulating currents between the primary transformers and causes the absorption of reactive power (MVAr) on the 33kV network. This can help to reduce high voltages on the 33kV network and above, and is provided as a Balancing Service to NG ESO when enabled across multiple CLASS controlled substations. This is not currently a service that the ENWL CLASS system provides to NG ESO. However, the system is equipped with this capability so this may be offered in the future if the demand for reactive power support increases or the CLASS system is adopted by other DNOs.

When activated, the tap stagger function could also release additional capacity for local 33kV connected DG that is operating through an ANM system as illustrated in Figure 5-7. In this example, the 33kV DG is curtailed due to a local voltage constraint. However, the absorption of reactive power has caused a reduction in network voltage.

In response, the ANM system could decrease the curtailment limit and allow ANM generators to increase their output. This in turn could increase the network voltage once again and decrease the cumulative value of the service provided to NG ESO and counteract the objective of the CLASS tap stagger operation.

The tap stagger also creates additional network losses due to circulating currents and additional thermal loading of the primary transformers. This can reduce the capacity of the primary substation for additional demand into the 11kV network and below. As such, the cost of the additional losses caused by the activation of the tap stagger function will be less justifiable if the objective of the function is nullified by the ANM system.

This potential ANM and CLASS conflict is demonstrated in Figure 5-12 below which illustrate the impact of the tap stagger and the response of the ANM system on network voltage. As seen in the diagram, the voltage improvement associated with the initial staggering of the tap changers is mitigated by the increase in DG output.

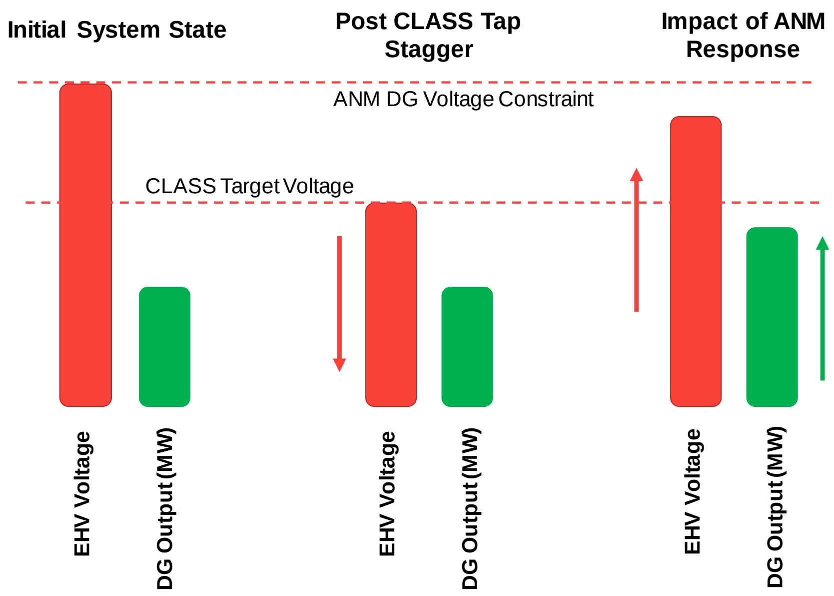

Figure 5-12: Illustration of the impact of tap stagger CLASS action and ANM system action on EHV voltage and DG output in Test Case 2C

5.2.4 TEST CASE 2D – TRIPPING OF CIRCUIT BREAKER FOR PRIMARY FREQUENCY RESPONSE

The Automatic Primary Frequency Response (APFR) function can be provided to NG ESO by the CLASS system as a firm frequency response (FFR) product. This service is not currently provided to NG ESO by ENWL. However, the CLASS system has this inherent capability and this service may be offered in the future by ENWL or other DNOs. If used, the function operates when an under-frequency threshold of 49.7Hz is detected by the AVC relays within the substation. This triggers the operation of one circuit breaker on the lower voltage side of one of the primary substations.

The network demand is then shifted from two transformers to one causing an immediate reduction in network voltage. This reduction in voltage then reduces the net demand on the network and helps support the recovery of the frequency to 50Hz.

The sudden disconnection of one of the two parallel transformers will reduce network voltage and consequently reduce the demand on the network. Similar to Test Case 2A, the ANM system will then further curtail any ANM connected generation operating at the export constraint of that portion of the network due to the reduction in demand which was reducing the export from the generation.

The primary frequency response is designed to operate within 0.5 seconds of an event and operate for at least 30 minutes. This is well within the timeframes for an ANM system to respond and counteract this action.

Consequently, this uncoordinated action from the ANM system will counteract the objective of the initial CLASS APFR action by offsetting the intended decrease in net demand on that area of the network. This will reduce the effectiveness of the APFR function as an FFR service to NG ESO.

The cumulative effect of this is illustrated in Figure 5-13 below where the Net Demand stays the same despite a decrease in customer demand initiated by the CLASS system.

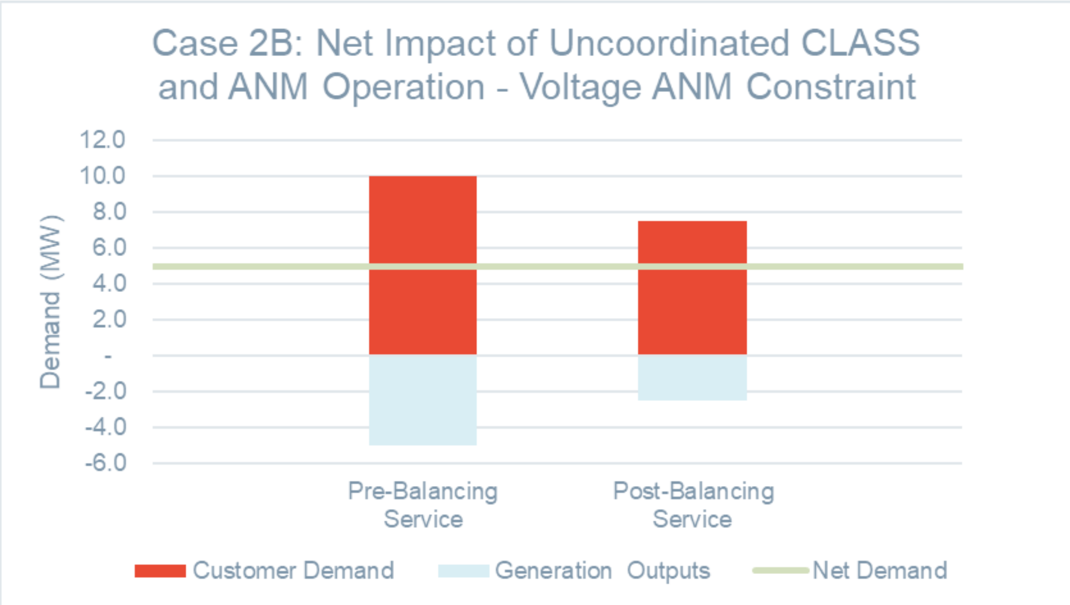

Figure 5-13: Cumulative effect of the actions of the CLASS and ANM systems on net demand before and after the balancing service request in Test Case 2D

Similar to Test Case 2B, if the ANM controlled generators are constrained by voltage, disconnection of one of the two parallel primary transformers could in fact release additional capacity for further ANM generation output. This is the opposite effect to the thermal ANM constraint previously described. In this case, the voltage drop will both reduce the demand from customer loads, increase the output from generation and increase the scale of the service provided to NG ESO. Therefore, this action by the CLASS system can also create synergies between the ANM systems and the primary frequency response service that is being provided to NG ESO by the CLASS system.

5.2.5 BENEFITS OF BETTER COORDINATION

The better coordination of ANM control systems with the procurement of Balancing Services from the CLASS system has the potential to deliver the following benefits:

- Maximise the ability of future CLASS systems to deliver frequency and reactive power services to NG ESO;
- Allow DNOs to more accurately report the availability of frequency and reactive power services that they can provide to NG ESO through the year as per the requirements of the GB Grid Code;

- Prevent unnecessary reduction in output from low carbon generation during the provision of Balancing Services to NG ESO;
- Allow the CLASS systems to intelligently and fairly balance the need to maximise output from low carbon generation, whilst offering frequency and reactive power Balancing Services to NG ESO which may conflict; and
- Maximise future revenue for both generators through increased generation and for DNOs when participating in Balancing Services.

5.3 TEST CASE 3

The criteria for generators and demand customers to participate in Balancing Services vary from service to service. In some cases, ANM generators are prevented from participating as their availability cannot be guaranteed, whilst in other cases ANM generators can participated but may be subject to non-delivery penalties if ANM curtailment prevents them from delivering the contracted Balancing Service.

As such, Test Case 3 investigates the risks and consequences associated with ANM generators participating and not participating in Balancing Services. This is split into two examples, Test Cases 3A and 3B, which are further described below.

5.3.1 TEST CASE 3A – ANM GENERATOR DEFAULTS ON BALANCING SERVICE DUE TO CONSTRAINTS

5.3.1.1 Description

Test Case 3A involves a situation in which NG ESO has procured a Balancing Service from an ANM generator. Although ANM generators are disqualified from participating in some Balancing Services, such as ODFM, there are no contractual restrictions on their ability to provide some other services.

If an ANM generator is contractually able to provide a Balancing Service by increasing its export, there is a risk the generator will default on the service when called upon due to being constrained by the ANM scheme at that time. This failure to provide the service may make the original issue more severe, adding more risk to the network and so also to security of supply. NG ESO will need to procure and dispatch the service from another generator, increasing the cost of balancing the system, which is ultimately passed onto the consumer.

Figure 5-14 shows the parties involved in Test Case 3A and the interactions between the ANM generator and NG ESO Balancing Service control room.

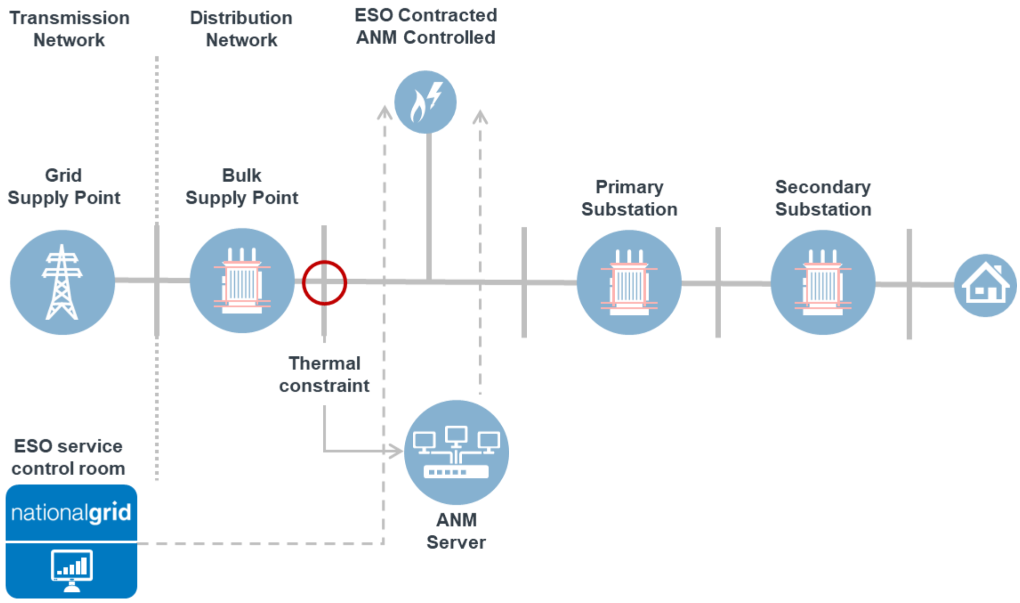

Figure 5-14: Example schematic of the parties and interactions involve in Test Case 3A

Considerations with respect to how often ANM controlled generation is constrained are important in defining the level of risk associated with its participation. Constraining these generators via curtailment of their output can be due to network conditions (e.g. network generation and demand patterns may result in network thermal and voltage constraints) or caused by outage of network assets. The former tends to be more prevalent and is relatively more predictable while the latter is less predominant and inherently unpredictable. Thus, how often curtailment occurs will vary across different ANM schemes on different distribution networks, dependent on how constrained the network is. It will also depend on the generators position in the LIFO stack, which impacts the likelihood of curtailment.

5.3.1.2 Benefits

A better understanding of the risks associated with the participation of ANM generators in Balancing Services and solutions that mitigate these risks without reducing the liquidity in the market could deliver the following benefits:

- Reduced risk of an ANM generator with a Balancing Services contract from being called upon when it is constrained or unable to respond;
- Reduced risk to security of supply as NG ESO can ensure that it is calling upon generators that can respond as required;
- Lower costs to consumers as the cost to NG ESO of balancing the system will be lower; and
- A more detailed understanding of the likelihood and consequences of non-delivery for each balancing service or product. This will inform which services ANM generators should participate in without concern, and what can be done to reduce the risk to the system to an acceptable level.

5.3.2 TEST CASE 3B –ANM GENERATORS UNABLE TO ACCESS BALANCING SERVICES MARKETS

5.3.2.1 Description

Where Test Case 3A considers the potential conflicts and risks associated with ANM generators participating in Balancing Services markets without better coordination, where needed, Test Case 3B considers the negative impact of excluding these generators. The number of generators connected to the network under an ANM scheme is increasing and is likely to continue to increase as networks become more constrained. These generators are prevented from participating in some Balancing Services (explicitly in the case of new balancing service ODFM) even when there is capacity in the local network to facilitate their participation. Many ANM generators are unconstrained for the vast majority of the year and so have the potential to provide Balancing Services most of the time. While increased use of ANM is likely to increase the extent of curtailment, there will still be significant periods of time at which the ANM is not actively curtailing (if this were not the case, generators would be unable to flow power onto the network and so would not have an investable business case for development). Blocking participation in Balancing Services reduces liquidity in Balancing Services markets by preventing these generators from accessing it, leading to higher costs of Balancing Services, which is ultimately passed on to the consumer.

Generators are generally offered an ANM connection where a non-ANM connection would require them to pay for network upgrades to create more capacity on the network. This alternative option will generally be available to customers and so, if they were planning on providing Balancing Services to NG ESO once connected, they would have a route to access the Balancing Services markets. Additionally, by choosing an ANM connection investment in the network is being deferred, but this investment will be needed at some point in the future to maintain overall confidence in service delivery.

Commercial and technical solutions are required to allow ANM generators to participate by allowing NG ESO to understand the level of risk associated with the portfolio of generators it has contracted with for each Balancing Service. Solutions could be different for different types of generators and different services. Non-curtailable generators in ANM areas and generators with standard connections will still provide Balancing Services but allowing ANM generation to access the market will increase liquidity. The increase in risk through allowing this access to generators with a higher risk of defaulting will need to be balanced with the counterfactual, as there is still a risk that non-curtailable generators in ANM areas and those with standard connections may default on the service, especially for generators with single circuit connections. However, there is also a risk of ANM generators defaulting on the service due to ANM system failure as well as curtailment. Arrangements as to how the liability and risk will be shared across the parties will need to be determined.

Additionally, the risk of allowing access to ANM generators will also depend on how critical the service is, and whether the service is localised (in which case access to parties is limited and high confidence is needed for delivery) or a national service (where there is more diversity and a greater spread of resources). For example, reactive power services must be provided at a local level, whereas frequency response and reserve services can be procured nationally.

5.3.2.2 Benefits

Coordination of ANM and Balancing Services, allowing ANM generators access to Balancing Services markets, will lead to the following benefits:

- ANM generators entering the Balancing Services market would increase market liquidity;
- More competition is likely to lead to lower bid prices and lower overall costs for consumers;
- Greater market liquidity and diversity of options will increase security of supply; and
- Greater diversity across the ANM connected portfolio can be used by NG ESO.

6 HIGH LEVEL ASSESSMENT OF BENEFITS

Before proceeding to the next stage of the project, we have undertaken a high-level quantitative assessment of the potential benefits of better coordination. This is primarily to ensure that the issues identified are sufficiently material to warrant continued development.

Focussing on distribution ANM (including that which manages constraints at the transmission to distribution interface), we have assessed the impact of:

- Test Case 1A and 1B (counteraction of incrementing and decrementing services) on the BM; and
- Test Case 3B (ANM generators unable to access Balancing Services markets) on the BM.

These examples on distribution ANM schemes have been selected as these Test Cases are likely the most prevalent and there is sufficient data in the public domain to enable detailed analysis of the procurement of the Balancing Service.

This section focusses purely on the quantifiable benefits. But the better coordination may also have significant non-quantifiable benefits, including:

- Improved security of supply – in order for security of supply to be maintained, NG ESO must be in a position to dispatch generators (and DER more broadly) with confidence that the desired response at system level will be observed. Better coordination will contribute to that confidence in respect of both ANM connected generation and non-curtailable generators behind an ANM scheme; and
- Greater ANM uptake – ANM schemes deliver material benefits for consumers by enabling new, often low carbon, generation to connect without the need for costly and potentially disruptive network reinforcement work. Improved coordination will resolve some uncertainty faced by new generators considering ANM connections by clarifying the regulatory and commercial position regarding their provision of Balancing Services.

6.1 ASSUMPTIONS AND LIMITATIONS

To quantify the impacts, it has been necessary to make several assumptions.

6.1.1 ANM CURTAILMENT

Engagement with DNOs has revealed that the majority of ANM schemes on the distribution networks today, and those in development, are managing renewables-driven network constraints. We also understand that levels of curtailment are very low and expected to remain relatively low for the foreseeable future.

So, when required to make assumptions on when ANM schemes curtail generators (e.g. the times at which ANM curtailment could counteract Balancing Services dispatched by NG ESO) we have assumed curtailment occurring 1% of the year (~88 hours) at times of high wind and solar output based on the observed behaviour of WPD ANM schemes.

6.1.2 PARTICIPATION IN THE BM

Under current market conditions, participation of generators connected to the distribution network is relatively low. But based on the direction of travel by NG ESO and market participants we have assumed all distribution connected assets are:

- Able to participate in BM due to different and new routes available; and
- Participation from distribution connected assets will increase over time.

So our analysis assumes BM participation from distribution connected assets is widespread.

6.1.3 BM BASELINE

We have used 2019 data as our baseline for the BM. We have analysed all accepted Bids and Offers in all settlement periods in 2019, filtering out those which are "system flagged" (typically those dispatched by NG ESO for constraint management). There is no strong reason why 2019 should not be representative of future years, but we recognise that the assumption of greater participation from distribution connected assets as described in Section 6.1.1 will impact market dynamics more broadly. There are also numerous other market developments in progress, including changes to the Contracts for Difference (CfD) arrangements and deployment of subsidy free renewables.

The use of 2019 data as representative of future years is therefore a significant simplification, but one which does not undermine the high-level analysis undertaken.

6.1.4 BM BIDDING BEHAVIOUR

We have focused on gas, wind and solar generators as the most prevalent technologies both on ANM schemes and non-curtailable behind ANM constraints. BM Bid/Offer behaviour for each has been determined as follows:

- Gas – Bid/Offer behaviour is based on the marginal cost of generation, using 2019 gas prices, carbon prices, and typical efficiency rates and operation and maintenance (O&M) costs. We have then assumed that:
  - In settlement periods where the Day Ahead power price is more than the marginal cost of generation plus a £5/MWh margin, gas plant will choose to run (in reality this is a conservative assumption, as generators will typically run for profit lower than this £5/MWh margin). As a result, it will only provide Bids in the BM, priced at its avoided cost of generation.
  - In settlement periods where the Day Ahead power price is less than the marginal cost of generation plus £5/MWh, gas plant will choose not to run. As a result, it will only provide Offers in the BM, prices at its marginal cost of generation plus a £2.50/MWh margin accounting for start-up costs.
- Wind – only Bids are provided in the BM, and only in settlement periods where wind generation was active (determined using load profile data for 2019). We have assumed that Bids are priced at the Renewable Obligation Certificate (ROC) price (effectively the lost revenue to the generator of not running) plus a small element of variable operating cost of £5/MWh.

- Solar – as with wind, but solar typically does not incur any variable O&M (it has no spinning turbine) so the price is set based only on the lost ROC price. Some solar will be connected under the Feed in Tariff (FiT) scheme, but this will typically be very small scale and so less likely to participate in the BM; larger scale solar which is more likely to participate in the BM is also more likely to be under the ROC scheme.

6.1.5 LIMITATIONS

This analysis focuses on the cost of both counteraction and artificially low liquidity on the BM alone. There will also be impacts on other Balancing Services which will be quantified later in the project, with BM analysis being sufficient for the high-level assessment at this stage.

We have also not considered in detail the interaction between the two Test Cases considered – where improving BM liquidity (under Test Case 3) may diminish the benefits available from avoiding counteraction (Test Case 1) as clearing prices will be lower. We expect this interaction to have a relatively small impact, so have assumed the benefits are additive.

6.2 IMPACT OF TEST CASES 1A AND 1B ON THE BALANCING MECHANISM

Test Case 1 focuses on the risk of actions instructed under Balancing Services being counteracted by ANM schemes. In the context of the BM, this is most easily demonstrated by an example in which the ESO accepts a BM Offer (i.e. increasing output) from a non-curtailable generator in an ANM area at a time at which the ANM constraint has already been reached. In this instance, the ANM scheme will curtail an ANM generator to prevent the constraint limit being breached. This is Test Case 1A and is described in detail in Section 5.1.1.

The issue may also arise if NG ESO accepts a BM Bid (i.e. decreasing output) from a non-curtailable generator in an ANM area at a time at which the ANM scheme is curtailing other generators. In this example, the reduction in output from delivering a BM Bid will manifest as available headroom at the constraint, so the ANM scheme will lift some of the curtailment. This is Test Case 1B and is described in detail in Section 5.1.2.

In both cases, NG ESO has procured a service because it requires a change in system demand which has not been delivered. As a result, the likely outcome is that NG ESO will be forced to procure the same service from another provider in order to secure the response it requires.

6.2.1 METHOD OF QUANTIFICATION

We have quantified the impact of counteraction by assuming that:

- For each 1MW of BM Bid/Offer which is counteracted, NG ESO is forced to procure an additional 1MW Bid/Offer; and
- That additional 1MW Bid/Offer is procured at the marginal price, i.e. the price of the most expensive Bid/Offer in the settlement period in question.

In addition, we have assumed that in periods when the system as a whole is "long" (i.e. NG ESO procures more bid volume than offer volume to achieve a net reduction in generation) that only Bids are counteracted, and vice versa. In reality this is not the case – NG ESO procures both Bids and

Offers in almost all time periods as it seeks to balance supply and demand. But the simplification will, if anything, result in an under-estimate of the impact of counteracted Bids and Offers.

6.2.2 RESULTS FOR WIND AND SOLAR

Based on 2019 data, we can assume that Bids from wind and solar were only accepted in settlement periods when:

- The system was long; and
- The price of the marginal accepted Bid was lower (more expensive[35]) than our assumed Bid for wind or solar respectively.

This occurred in 823 settlement periods (5% of the year) for wind and 313 settlement periods (2% of the year) for solar, with solar being lower due to its lower load factor.

Based on our assumption on the times of curtailment, 40 of the 823 settlement periods (5.0%) for wind and 40 of the 313 settlement periods (17.2%) for solar align with times of ANM curtailment. While these are relatively low percentages, both are above the average 1% curtailment in the year, which, as expected shows a correlation between high Bid acceptances (occurring at times of low demand and high renewables on the system as a whole) and ANM curtailment (occurring at times of low demand and high renewables on ANM-controlled areas of the network).

In those settlement periods, Bids from non-curtailable wind/solar generators behind ANM schemes would be accepted, so those generators would reduce output as instructed. But the ANM scheme behind which they are connected is actively curtailing at the time, so the ANM scheme would lift some curtailment on other generators, leaving NG ESO with no net change in power flow and forcing it to accept another Bid at the marginal price. If accepted Bids from 1MW of wind and solar were counteracted at times of ANM curtailment in 2019, the cost to consumers would have been ~£1.0k/year and ~£1.3k/year respectively.

From our engagement with the DNOs, we estimate that there is at least 1.1GW of wind and 5.6GW of solar which is non-curtailable in an ANM area. But the extent to which Bids from those generators will be counteracted is limited by capacity connected on ANM schemes – 0.7GW of wind and 2.6GW of solar. This gives potential GB-wide impact of ~£4.2mn/year from counteracted Bids from wind and solar.

6.2.3 RESULTS FOR GAS

Based on 2019 data, we can assume that:

- Bids from gas were only accepted in settlement periods when the system was long and the price of the marginal accepted Bid was lower (more expensive) than our assumed Bid for gas. This occurred in 3,239 settlement periods (19% of the year) in 2019

[35] The Bid price reflects the amount the generator is willing to pay to NG ESO to not export. Non-subsidised generators typically set their Bid price at their marginal cost of generation (so high marginal cost generators submit high Bids and are taken off the system first) while subsidised generators will submit negative Bids reflecting lost subsidy revenue (e.g. ROC value)

- Offers from gas were only accepted in settlement periods when the system was short and the price of the marginal accepted Offer was higher than our assumed offer for gas. This occurred in 4,920 settlement periods (28% of the year) in 2019

Based on our assumption on the times of curtailment, 72 of the 8,159 settlement periods (0.9%) align with times of ANM curtailment, the majority of which were accepted Offers and do not correspond with settlement periods in which wind or solar Bids would have been accepted.

In those settlement periods, Bids or Offers from non-curtailable gas generators behind ANM schemes would be accepted and would be counteracted, leaving NG ESO with no net change in power flow and forcing it to accept another Bid or Offer at the marginal price.

If accepted Bids and Offers from 1MW of gas were counteracted at time of ANM curtailment in 2019, the cost to consumers would have been ~£2.9k/year.

From our engagement with the DNOs, we estimate that there is at least 350MW of gas which is non-curtailable in an ANM area, giving an estimated GB-wide impact of ~£1.0mn/year from counteracted Bids and Offers from gas.

6.2.4 SUMMARY OF TAST CASES 1A AND 1B ON THE BM

Based on our assumptions for the times or curtailment and BM bidding behaviour, the total impact of Bids and Offers from wind, solar and gas which would be counteracted could cost consumers ~£5.3mn/year.

6.3 IMPACT OF TEST CASE 3 ON THE BALANCING MECHANISM

Test Case 3B focuses on the risk that, because ANM generators are exposed to non-delivery penalties if the ANM scheme curtails their output when instructed by NG ESO, ANM generators may choose not to participate in Balancing Services all the time. But in many settlement periods, ANM schemes will not be active, so ANM generators could provide services. As a result, liquidity could be higher in Balancing Services markets. This is described in detail in Section 5.3.

6.3.1 METHOD OF QUANTIFICATION

We have quantified the impact by assuming that each **additional** 1MW BM Bid/Offer from a new participant which is below the marginal price will displace the marginal 1MW Bid/Offer which would have been accepted without that additional 1MW.

If a large volume of Bids or Offers were added to the BM Bid/Offer "stack", it would at some begin to drive the price (i.e. it would displace all more expensive generators and become the marginal price setter). While we have not explicitly accounted for this, we have added 10% headroom to the Bids for wind and solar (for both of which we are considering large volumes) to increase the likelihood of a material volume of Bids being between the actual wind/solar Bid and the marginal Bid which wind/solar can displace.

6.3.2 RESULTS FOR WIND AND SOLAR

As with Test Case 1, in 2019 there were 823 settlement periods when Bids from wind would have been accepted and 313 settlement periods when Bids from solar would have been accepted because the Bids from wind and solar are lower cost than the marginal Bid in those settlement periods.

Based on the marginal Bid in those periods (which could have been displaced by additional wind or solar participating in the BM), the benefit of an additional 1MW of wind and solar participating in the BM would have been £3.3k/year and £0.8k/year respectively.

From our engagement with the DNOs, we estimate that there is at least 0.7GW of wind 2.6GW of solar which is ANM connected. Even if only 10% of this were to respond to the removal of the barrier to BM participation, the benefit to consumers could be ~£0.2mn/year from wind and ~£0.2mn/year from solar.

6.3.3 RESULTS FOR GAS

As with Test Case 1, in 2019 there were 8,159 settlement periods when Bids or Offers from gas would have been accepted.

Based on the marginal Bid or Offer from other technologies in those periods (which could have been displaced by additional gas participating in the BM), the benefit of an additional 1MW of gas participating in the BM would have been £162k/year.

From our engagement with the DNOs, we estimate that there is at least 170MW of small gas generation which is ANM connected. Even if only 10% of this were to respond to the removal of the barrier to BM participation, the benefit to consumers could be ~£2.8mn/year.

6.3.4 SUMMARY OF TEST CASE 3 ON THE BM

Based on our assumptions on the volumes of generation which could enter the BM if the barrier to participation were removed, the resulting improved market liquidity could save consumers ~£3.2mn/year.

6.4 SUMMARY OF BENEFITS ASSESSMENT

Table 6-1 summarises the assessment of benefits of better coordination between ANM schemes and the Balancing Mechanism. As noted in the limitations section, this is an assessment only the BM with current accepted and connected ANM schemes. As a result, there is potential both for other benefits from other Balancing Services in the short term, and increased benefit of better coordination with the BM as use of ANM schemes increases over time.

Table 6-1: Summary of Assessmnet of Benefits

	Gas	Wind	Solar	Total
ANM Volume (MW)	170	717	2,664	3,850
Potential Cost of Counteracted Bids (£mn/year)	1.0	0.7	3.5	5.3
Potential Benefit of Increased Liquidity (£mn/year)	2.8	0.2	0.2	3.2
Total Potential Benefit (£mn/year)	3.8	1.0	3.7	8.5

7 EXISTING COORDINATION

Through the course of the project, we will be seeking mitigations to the risks identified in Section 4. This section focuses on any existing mitigations, which are broadly of two types:

- Restrictions on the participation of ANM generators or non-curtailable generators in an ANM area in Balancing Services markets; and
- Coordination between network companies.

7.1 RESTRICTIONS ON PARTICIPATION

There are a number of examples of restrictions on ANM generators participating in Balancing Services markets. With a lack of clear and consistent definitions in the industry on ANM schemes and generators behind non-ANM-managed constraints, there is an issue of ambiguity around participation in Balancing Services.

A key example is frequency response services. In a previous (2016) invitation to tender for Enhanced Frequency Response[36] (EFR), it was clearly stated that to participate, “assets must not be in an existing area of Active Network Management”. This creates some ambiguity, specifically regarding whether it applies to non-curtailable generators in an ANM area, or just ANM generation. Engagement with DNOs has revealed that non-curtailable generation in an ANM area will not always be aware that an ANM system is in place. In many cases it is likely that generators will be aware of the ANM scheme as the DNOs typically undertake proactive stakeholder engagement, but there is no formal requirement for those generators to be informed. Hence any restriction that excludes generators in an ANM area may not have the desired effect under current arrangements as the DER would not always be aware that it is excluded.

NG ESO recognises that restrictions on participation in Balancing Services varies between different services which may be for different reasons. However, for some services such as frequency response, a blanket restriction on any participation from ANM generators is applied. For others, such as the Balancing Mechanism, generators are responsible for delivery – so while there is no contractual barrier to ANM generators participating, they will be exposed to non-delivery penalties if they do not deliver, even if the reason they did not deliver was ANM curtailment.

The guidance document in support of the recent Optional Downward Flexibility Management[37] (ODFM) service, launched by NG ESO in May 2020, states that, to participate, participants “must not have a condition in their DNO connection agreement whereby they are signed up to an Active Network Management (ANM) Scheme / Flexibility Connection”. This retains some of the ambiguity of the EFR service restrictions. The frequently asked questions document[38] for the service suggests that service from providers should not be counteracted by ANM generators, which would exclude those generators

[36] EFR was the predecessor to the suite of frequency response services now procured by NG ESO.

[37] https://data.nationalgrideso.com/backend/dataset/812f2195-4e96-4bfd-8bf0-06c3d0126c57/resource/1b2d5573-8b91-4608-8082-d93815d970bc/download/odfm-guidance-doc-v.3-19.05.20.pdf

[38] https://data.nationalgrideso.com/backend/dataset/812f2195-4e96-4bfd-8bf0-06c3d0126c57/resource/655d6338-ef05-471e-b829-9621e2cc7789/download/odfm-faq-document-10.06.20.pdf

behind an ANM-managed constraint but not curtailed by the system. NG ESO has recognised that this may prevent a number of participants, and work is ongoing to determine whether the rules on participation can be relaxed.

The operation of GEMS in the future may also restrict generators that are subject to curtailment from participating in Balancing Services. Currently, as NG ESO will have complete visibility over the system, it is considering that there should not be restrictions. However, cost implications need to be taken into account, considering compensation for curtailment of generators and payments made for Balancing Services.

7.2 COORDINATION BETWEEN NETWORK COMPANIES

NG ESO generally has limited interaction with the DNOs on ANM schemes on their networks, with limited examples detailed below. However, it is recognised that as the schemes become more widespread that better levels of communication and coordination will become important, from the planning phase down to real time operational data. Communications infrastructure (in the form of ICCP links) is being put in place as part of the Regional Development Plans (RDPs).

Any existing and planned interaction between DNOs and NG ESO on the operation of ANM schemes is summarised in Table 7-1.

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Table 7-1: Existing coordination between network companies

DNO	Coordination with NG ESO
SPEN	**Current schemes:** digital alarms indicating current ANM operation **Future schemes:** integration with GEMS and NG ESO on Dumfries and Galloway project, some ESO requests can be rejected by SPEN
SSEN	**Current schemes:** information on planning timescales only, not operational **Future schemes:** SSEN is engaged in the South West Operational Tripping Scheme (SWOTS) which involves ESO, TO and DNO coordination
ENWL	**Current schemes:** not applicable (no ANM schemes in operation) **Future schemes:** coordination not currently built into design, but early discussions on ICCP link
NPg	**Current schemes:** limited coordination on one scheme **Future schemes:** no planned coordination
UKPN	**Current schemes:** limited operational data on transmission constraint scheme **Future schemes:** enterprise-wide system now in place across network with the timeline for roll-out now driven by constraints materialising
WPD	**Current schemes:** limited coordination on existing schemes **Future schemes:** ICCP link is in build phase, allowing for NG ESO visibility at GSP level

SPEN shares information with NG ESO on its existing ANM schemes in Dunbar and Berwick, including the level and duration of curtailment. However, it is uncertain if and how this is used. Much more information will be shared between NG ESO and SPEN when GEMS is live, with actions taken by GEMS going through the ANM system automatically to applicable DER . It is yet to be agreed how the two systems will interact. However, the below shows an example of how interaction could take place through two modes of operation of the ANM scheme:

- Mode 1: The ANM scheme acts as normal with no interference from GEMS; and
- Mode 2: ANM is instructed to hold headroom if a Bid is accepted from an ANM generator in the BM, or a Balancing Service is instructed. This mode remains in operation for as long as the

instruction lasts, although if it were to cause SPEN issues on its own network, it can overrule the NG ESO instruction.

The new ENWL ANM system design does not integrate coordination with NG ESO; however, it is possible that an ICCP link will be installed in the future to provide information on the operation of the system.

WPD is in the process of developing an ICCP link with NG ESO, which will give NG ESO visibility over each DER type aggregated at GSP level. This will allow for the derivation of headroom and footroom at each GSP. However, current communication with NG ESO on ANM coordination is limited.

NPg has very little coordination with NG ESO on its existing schemes, and older schemes can cause issues of coordination with Balancing Services (as described in Section 4).

SSEN also identified that it had very little coordination with NG ESO on operation of its ANM schemes, and any information passed on tended to be at the planning stage of schemes and would not be fit for whole system coordination.

The issue of coordination between NG ESO and DNOs has been recognised as part of the Regional Development Plan (RDP) for the South West Peninsula, on which more detail is given in Section 9.2.1. In the implementation of the scheme, a process for assessing and managing service conflicts between ANM operation and NG ESO services is to be trialled.

8 CONCLUSIONS

All DNOs either have ANM schemes in use or are in the process of deploying them. Our findings from research and engagement with the DNOs and NG ESO has confirmed our initial hypothesis that a lack of coordination will give rise to poor outcomes. This is most notable in respect of:

- **ANM generators**, which either risk defaulting on provision of Balancing Services due to ANM curtailment, or face restrictions on participation that unnecessarily reduce Balancing Services market liquidity at times when the ANM system is not active. This can potentially increase cost to the consumer; and
- **Non-curtailable generators in an ANM area** can participate in Balancing Services but in some instances, curtailment actions taken by the ANM will counteract (or worse, over-curtail) such actions, resulting in NG ESO paying for a service but not seeing any net change in power-flow (or worse, the opposite change to that which it sought). This is both costly for consumers and a risk to security of supply.

A clear benefit of better coordination lies in increased security of supply, derived from NG ESO having greater certainty that it will see the expected change in usage when it instructs Balancing Services.

But there is also a financial cost of poor coordination. Based only on poor coordination between the Balancing Mechanism and ANM schemes, the costs to consumers could be around £8.1mn/year. The actual cost of poor coordination between ANM and Balancing Services more broadly is likely to be higher than this as there will be cost associated with other Balancing Services which we have not yet quantified.

There are some examples of coordination which are already in place or being considered for future ANM schemes. Most notably, this is in the case of the Dumfries and Galloway scheme where the ANM system will have two operational “modes” enabling it to ensure some Balancing Services actions are not counteracted, although this is not yet integrated with the roll out of the GEMS system, and the way in which the systems will coordinate has not yet been agreed. Coordination is neither consistent nor widespread. The above approach may also not be optimal in other circumstances, for example where GEMS is not in place. There are many other options to be considered, some of which we have discussed with stakeholders, including:

- Amending Balancing Services market rules to enable ANM customers to participate in Balancing Services;
- Better information exchange and use of ANM data by NG ESO;
- Update to commercial frameworks, for example on how NG ESO values balancing actions; and
- Greater involvement from the DNO/DSO in the procurement of NG ESO services from DER.

These potential solutions will be considered further in the remainder of the project. Given the risk to security of supply from uncoordinated ANM schemes and benefits of around £8.5mn/year, we consider there is merit in continuing to the next stage of the project, which will involve a more detailed scoping of the options for resolution and subsequent analysis to determine the optimal coordination approach.

9 APPENDIX A

This Appendix gives details relevant innovation projects as noted in Section 2.1.3.

9.1 DISTRIBUTION NETWORKS

As many DNOs are accommodating increasing levels of DER on their networks, innovative ways to manage their system optimally are being explored. One solution is the implementation of ANM schemes to manage distribution constraints. ANM schemes have been increasingly deployed across the distribution network and the use of ANM is predicted to grow. By limiting the output of DER at certain times, ANM schemes allow increased connection capacity without reinforcement. All of the DNOs in GB have utilised ANM schemes on their networks to varying degrees, but a coordinated approach has not been taken across the country. Some examples of these schemes are:

- Scottish and Southern Energy Networks (SSEN) – Orkney Smart Grid RPZ (2009-Present)[39];
- Northern Powergrid (NPg) – Customer Led Network Revolution (CLNR) (2010-2014)[40]
- UK Power Networks (UKPN) – Flexible Plug and Play (2011-2014)[41], Power Potential (2017-Present)[42,43];
- Western Power Distribution (WPD) – Lincolnshire Low Carbon Hub (2012-2015)[44];
- Electricity Northwest Limited (ENWL) – Customer Load Active System Services (CLASS) (2014-2015)[45]; and
- Scottish Power Energy Networks (SPEN) – Dumfries and Galloway ANM (2018-2023)[46].

These schemes are summarised below.

9.1.1 ORKNEY SMART GRID[47]

SSEN's ANM approach on Orkney was devised to make better use of the existing network by instructing generators to control their output in real time to match the available network capacity. It allows the power flows at several points on the network to be monitored and power flows from multiple new renewable generators to be controlled. The technology is based around a central controller that collects data from different points distributed around the network.

[39] https://www.ssen.co.uk/OrkneySmartGrid/
[40] http://www.networkrevolution.co.uk/
[41] https://innovation.ukpowernetworks.co.uk/projects/flexible-plug-and-play/.
[42] https://www.nationalgrideso.com/future-energy/innovation/projects/power-potential
[43] https://innovation.ukpowernetworks.co.uk/projects/power-potential/
[44] https://www.westernpower.co.uk/projects/the-low-carbon-hub
[45] https://www.enwl.co.uk/zero-carbon/innovation/key-projects/class/
[46] https://www.spenergynetworks.co.uk/pages/dumfries_and_galloway_integrated_network_management.aspx
[47] Operating the Orkney Smart Grid: Practical Experience, Smarter Grid Solutions, Scottish and Southern Energy, Jun. 09, 2011 http://www.cired.net/publications/cired2011/part2/MS4B2/1187.pdf

Under the ANM scheme, new generators are instructed to limit their power output to match the available export capacity within Orkney and to the mainland grid. The capacity available to these generators is derived from real-time network measurements and will depend on the level of demand and existing generation output on Orkney. The smart grid has enabled the same amount of renewable generation to be connected to Orkney's distribution network as would have been possible through conventional network reinforcement at a fraction of the cost.

The control logic behind the operation of the ANM scheme has been designed to be gradually implemented as New Non-Firm Generation (NNFG) units connect. Within each zone the NNFG units are approached for curtailment according to LIFO principles. This approach results in the creation of a NNFG priority stack with regards to access to capacity at any pinch point on the Orkney distribution network.

The control logic has been designed to easily accommodate the addition of NNFG units or measurement points in any existing or new zones. Adopting the nested control zone approach to ANM allows greater utilisation of the available network infrastructure.

9.1.2 CUSTOMER LED NETWORK REVOLUTION

NPg's CLNR project assessed the potential of novel smart grid network technologies, new commercial arrangements and customer flexibility solutions to provide cost-effective ways to prepare the UK electricity networks for the low carbon future.

The ANM system deployed for CLNR used real-time monitoring inputs and state estimation and optimisation rather than relying on pre-programmed rules. An ANM control system called the Grand Unified Scheme (GUS) control system was used in a series of largescale field trials. This control system was given control objectives and it then monitors relevant network parameters in real-time, runs network analysis to estimate states where measurements are not possible, determines the location of network issues and dispatches the optimum response based upon the types and location of the smart technologies and demand side management resources available. Under the control of the ANM scheme, NPg deployed a range of novel solutions and used advanced modelling techniques created by Newcastle University to predict, validate and scale-up the learning from the trials.

Following the outputs of CLNR, NPg have produced a route map to guide the development of smart grid technology and systems to 2050. Their proposed approach is hierarchical; DNOs can start with relatively simple forms of localised ANM to resolve local issues. Then, as more network constraints are created from the connection of more low carbon technologies, DNOs are likely to need to deploy more solutions; whether in isolation or combination. As the number of constraints and the number of solutions multiply, so does the need for more sophisticated wide area control systems to join up and add to the localised solutions delivered earlier. Safety and reliability have to be designed into the smart grid from the outset.

9.1.3 FLEXIBLE PLUG AND PLAY

UKPN's Flexible Plug and Play (FPP) project aimed to demonstrate how, through the integration of innovative technological and commercial solutions, cost effective connection of DG to constrained parts of the distribution network can be achieved. It delivered greater flexibility in accommodating cheaper and faster DG connections, as well as enabling previously unviable DG schemes to become feasible.

The FPP project focused on moving the DNO from the passive ‘fit and forget’ approach based on conventional network reinforcement to one that considers the active management of network constraints and generation export, driving an active ‘fit and flex’ approach that avoids or defers network reinforcement. The FPP project involved significant information and communication technology elements to solve power systems problems.

FPP used ANM to offer interruptible connections to developers connecting in a constrained network area on the basis of pro-rata principles of access. A quota was also applied to limit the total capacity of generation connected within the constrained area to a pre-agreed cap. Once the quota was reached, Last In First Out (LIFO) principles were applied for future connections.

A smart application was installed at UKPN’s control centre at Fore Hamlet, Ipswich, providing an ANM solution to monitor real time network parameters by the smart devices. The ANM manages the generators’ output using the generation controllers, which allows the DG export to track the real-time export capacity available within the real-time constraints on the distribution network. The ANM performs these functions while ensuring that the distribution network maintains its reliability and performs within operational limits.

The novel areas of the FPP ANM trial are:

- Integration and coordination of multiple smart solutions such as Quadrature-booster, Dynamic line rating, Automatic Voltage Controller and Remote Terminal Units (RTUs);
- Demonstration of generator control with an innovative commercial arrangement through the capacity quota;
- A system integration approach with open standard communications to integrate multi-vendor devices; and
- ANM communications over a purpose-built DNO communications platform.

The ANM trial was structured in various stages with a key focus on simulation and operational phases. The simulation phase ensured all functionalities were tested and proven on the live infrastructure with simulated elements. The system was closely monitored to ensure the expected performance was achieved. The FPP not only demonstrated the functionalities of ANM, it also made it possible for the constrained network to accommodate the connection of new generation within the project timescales. A total of 14 generators were signed up during this period. These generation customers would otherwise have had to pay large reinforcement costs to connect over significantly longer timescales if business-as-usual approaches were used; quicker and more cost effective connections of renewable generation to the distribution network were possible using the flexible approach in the trial.

9.1.4 LINCOLNSHIRE LOW CARBON HUB

WPD's Low Carbon Hub for East Lincolnshire was designed to test a variety of new and innovative techniques to allow low carbon generation to connect to the electricity networks, whilst avoiding the high costs that would normally be associated with more conventional methods such as network reinforcement.

Lincolnshire, being on the east coast, is suitable for a wide range of renewable generation types. These include onshore and offshore wind farms, large scale solar Photo Voltaic (PV) and energy from bio crops. However, many generators cannot connect to the distribution network closest to them due to the effects their connection would have on the operation of the existing network. These generators therefore tend to require long, new underground cable installations to connect them to more robust sections of the network. This project demonstrated six alternative techniques: network enhancements, commercial agreements, dynamic voltage control, 33kV active network ring, Flexible AC Transmission System (FACTs) Device and dynamic system ratings.

Of the range of techniques explored through this work, ANM was used to allow WPD to offer alternative connections: new, innovative commercial arrangements to allow generators to take advantage of the spare capacity in the network when it exists and introduces constraints on the output when the capacity does not exist.

ANM will continue to be rolled out by WPD across all four WPD licence areas with a commitment for ANM to be available everywhere necessary by the end of 2021. Each will use the Alternative Connection agreements developed as part of this project.

The project built a constraint estimation tool and demonstrated how the tool can be used to study:

- Alternative Connections under both normal and abnormal network configurations;
- How a generation developer can be provided with the necessary information to evaluate likely constraints; and
- The risk and suitability of accepting an alternative connection.

9.1.5 CUSTOMER LOAD ACTIVE SYSTEM SERVICES (CLASS)[48]

CLASS is a collective term used to describe the use of voltage management technologies on distribution networks, whereby voltage at a primary substation is varied to intentionally alter the level of power consumption at lower voltage connection levels. ENWL's CLASS project tested the ability of DNO primary substations to provide Balancing Services to NG ESO. It demonstrated that it is possible to use remote management of transformers on primary substations to deliver a rapid reduction or

[48] Assessing the impact of CLASS on the GB Electricity Market, Baringa, May 31, 2016 https://www.enwl.co.uk/globalassets/innovation/class/class-documents/assessing-the-impact-of-class-on-the-gb-electricity-market_redacted.pdf

increase in the underlying load. The project also involved developing the control and communications systems that would be required to access this capability.

These services are required to allow NG ESO to meet its statutory obligations for maintaining system balance in steady state:

- **Firm Frequency Response (FFR):** A very fast increase or reduction in consumption, which may be used for between 30 seconds and 30 minutes.
- **Fast Reserve:** A fast ramping reduction in consumption, which may be used for up to 15 minutes at a time.
- **Short Term Operating Reserve (STOR)**: A medium-speed ramping product which can be used for up to two hours at a time.
- **Reactive Power through the Enhanced Reactive Power Service (ERPS)**: A localised services that provides the absorption of reactive power within 2 minutes of an instruction.

The components of a primary substation that CLASS is focused on are the two transformers, its circuit breakers, and the control and communications equipment that needs to be installed:

- The transformers perform the function of stepping voltage up or down. Primary substation transformers are adjustable, in that the number of coils used to control the voltage can be varied by changing the position of contacts known as tap changers;
- Circuit breakers are used to route power through the substation and its transformers; and
- The "control equipment" is any power system electronics that are used to operate the tap changers, or the circuit breakers automatically or remotely.

The CLASS system uses Automatic Voltage Control (AVC) relays to adjust the position of tap changers and circuit breakers within Primary substations to reduce or increase network voltage and elicit a change in network loading or demand. This system is used for the following purposes:

- To reduce peak network loading to defer the need for network reinforcement due to the connection of additional demand;
- To minimise the consumption of network customers to directly reduce their electricity bills; and
- To provide support services to NG ESO.

The CLASS system was originally trialled as part of an innovation project headed by ENWL. The solution was then successfully adopted and rolled out as Business as Usual (BaU) by ENWL. To date the CLASS solution has been rolled out to 243 primary substations across ENWL's distribution network. Ofgem is currently undertaking a public consultation on the regulatory treatment of CLASS as a balancing service in the RIIO-ED2 network price control. The decision arising from this consultation will influence the wider GB roll-out of the CLASS approach amongst other DNOs.

The provision of frequency services is delivered by the CLASS system by activating or enabling the following functions:

- **Automatic Primary Frequency Response:** This function is enabled automatically on site when a relay detects a frequency of 49.7Hz, tripping the circuit breaker on the low voltage side of one of a pair of Primary Transformers. Shifting network loading from two transformers to one creates an immediate reduction in network voltage and helps to support the recovery of system frequency by reducing network demand.

- **Manual Primary Frequency Response:** This function in action is identical to the automatic function described above. However, the function is manually dispatched by NG ESO or ENWL to provide the immediate frequency response desired by tripping the circuit breaker of one of the Primary Transformers.

- **Automatic Secondary Frequency Response**: This function is activated automatically on detection of a frequency of 49.7Hz, causing both primary transformers to tap down to their lower tap setting. This reduction in tap position reduces network loading through the principals of CVR and helps to support the recovery of system frequency.

- **Tap Stagger Function:** This function is triggered automatically via the CLASS dashboard to create circulating current between the parallel Primary transformers. Tap stagger for VAR absorption works on a circulating current method – 7.5% of demand which generally gives a 2-tap difference, activated directly from the Demand Reduction Through Voltage Conservation (DRVC) dashboard. The estimated QMVAR absorption is shown on the dashboard.

The functionalities described above are well suited to provide the following services to NG ESO. Currently, ENWL is only providing secondary frequency response services to NG ESO through demand reduction through lowering of tap position.

9.1.6 POWER POTENTIAL[49]

Through the Power Potential project, UKPN and NG ESO are aiming to open up new markets for DER and generate additional capacity by alleviating transmission voltage constraints. The study is based in the South East region of the UK, where the connection of distributed energy resources is growing rapidly. The objective of the project is to create a regional reactive power market for DER connected to the distribution network to provide dynamic voltage control from DER and active power support for constraint management and system balancing to NG ESO.

Power Potential is structured into the following key deliverables:

- a commercial framework using market forces to create new services from distributed energy resources to NG ESO via UKPN; and

[49] Transmission & Distribution Interface 2.0 (TDI 2.0), SDRC 9.2 – Commercial and Detailed Technical Design, UK Power Networks and National Grid, https://www.nationalgrideso.com/document/103931/download

- a platform known as Distributed Energy Resources Management System (DERMS) to support technical and commercial optimisation and dispatch.

The DERMS solution will work as follows:

- gather commercial availability, capability and costs from each DER;
- run power flow assessments to calculate the possible availability of each service at the grid service point and present that information to us; and
- instruct each DER to change their set–point as required and monitor their response on the day power is required by us.

If successful, Power Potential could potentially save up to £412m for UK consumers by 2050. It could be introduced to 59 other transmission sites and produce an additional 3,720 MW of generation in the South East area by 2050.

9.1.7 DUMFRIES AND GALLOWAY ANM[50]

SPEN will implement an ANM scheme in Dumfries and Galloway to use DG to manage the transmission network constraints that affect the distribution network; this was previously done by the load management system (LMS), but the ANM scheme will result in fewer and more sophisticated DG constraint actions. As this ANM scheme alleviates transmission constraints using DG it must interface with NG ESO and is therefore more complex than the traditional ANM schemes used as business-as-usual solutions.

The ANM scheme will include intertrip functionality to manage constraints caused by transmission faults and monitor the whole network in real time. It has its own model of the transmission and distribution network; by continuously running calculations, the ANM knows what the true capacity of the network is at any moment. The ANM's controls can ramp individual DG sites down to a lower specific output level, rather than simply disconnecting all generators, giving a more granular and targeted export reduction.

The ANM scheme in Dumfries and Galloway will have the ability to select which generators to reduce/disconnect first according to number of methods, for example LIFO, the most technically efficient solution (the least MW removed from the system), the most commercially efficient solution (which takes into account generator constraint payments where these exist), and hybrids of these methods.

The ANM scheme's communication network aims to facilitate the participation of connected DG in the BM. The potential revenue from ancillary sources is likely to become increasingly important to developers' business models and so DG can be a new source of lower cost balancing and constraint services for the NG ESO. As many traditional providers of balancing services are coal plants, which are closing, finding new ancillary service providers is essential for system stability and security.

[50] Distribution Network Operator Innovation Roll-Out Mechanism (IRM) Submission Pro Forma, SP Distribution

9.2 TRANSMISSION NETWORKS

9.2.1 REGIONAL DEVELOPMENT PLAN – SOUTH WEST PENINSULA[51]

Regional Development Programmes (RDPs) were set up to provide detailed analysis of areas of the network that have large amounts of DER, leading to transmission/distribution network issues. The South West (SW) Peninsula RDP covers all Grid Supply Points (GSPs) on the SW Peninsula network: Axminster, Exeter, Abham, Landulph, Indian Queens, Alverdiscott, Taunton and Bridgwater GSPs. This network has been chosen because WPD and NG ESO identified that conventional transmission and distribution capacity issues could potentially limit the perceived volume of potential DER. This is because solar and wind resources are favourable in the region. The region is therefore expected to play a major part in meeting the future governmental green energy targets.

It was proposed that all new DER connections should include ANM capability. The key principles of this ANM are:

- Under normal operation, security of the distribution network will always be maintained by ANM ahead of accommodation of transmission services;
- The centralised Network Management System will latch instructions until those are withdrawn, i.e. it will not release intertripped generation until instructed; and
- The technical design of the ANM is developed towards holding headroom or foot room to accommodate transmission services in the future where it is appropriate to do so. This will not be possible until significant and difficult commercial interactions are resolved by the wider industry.

In control timescales, a process called scheduling is used to start planning the use of services, including those from DER, several hours ahead of real time. A forecast of DER output and where output and services will be curtailed owing to DNO constraints will be required in scheduling timescales. It is the intention of NG ESO and WPD to continue to innovate and look to develop a DNO input into scheduling activities.

The current volume of ANM connected DER is relatively low, which means that service conflicts between transmission and distribution network needs are not yet a material problem, but analysis shows that an increased number of actively managed distribution networks will mean the issue will become evident in the future. NG ESO may have directly procured additional services from DERs, which also need to operate in the bandwidth of capacity available on the DNO networks; many of these services will not be under direct control of the WPD ANM. For example, a frequency response provider will provide a service in the windows in their contract or via direct instruction. The actual output of the frequency response provider will be automatically adjusted by the DER's local controller and will increase/decrease output proportional to the difference between target frequency and actual frequency.

[51] Regional Development Plan, South West Peninsula Technical Report, National Grid and Western Power Distribution, Apr. 27, 2018 https://www.nationalgrideso.com/sites/eso/files/documents/WPD%20RDP%20South%20West%20Peninsula%20Technical%20Report_Final.pdf

Industry stakeholders, particularly through the ENA TSO-DSO working groups, have identified the potential for ANMs to, at times, conflict with embedded NG ESO services by negating service output. NG ESO services embedded in the DNO network may be impacted by ANMs either:

- For services which increment: If the ANM is active at the time (or does not have sufficient headroom), then the service effect will be negated seconds later following ANM action to curtail alternative generation.
- For services which decrement: If the ANM is active at the time, the controlled DER will "fill in" the space made by the service with the extent of the fill in being determined by the volume of other DG/DER being curtailed prior to the decrement service.

NG ESO will continue to procure Balancing Services from providers embedded in the distribution network and more ANM types of control systems are expected to be deployed in other areas of the system, so the risk of conflicting actions is expected to grow. The consequences to the system's operation would be that, at times when ANMs are active, services do not deliver the expected net output, requiring either additional services to be run at extra cost or presenting a risk to system security.

A process for assessing and managing service conflicts is to be trialled in the implementation phase of the RDP. In the dispatch phase the DNO will provide system limits and the transmission services will be dispatched by NG ESO within those limits.

9.2.2 REGIONAL DEVELOPMENT PLAN – SOUTH EAST COAST[52]

The South East Coast network has been chosen for an RDP, because UKPN and NG ESO identified that transmission capacity issues were beginning to impact customer connection dates. The area to be covered by UKPN's planned ANM scheme will be Bolney, Ninfield, Sellindge, Canterbury and future Richborough GSPs. UKPN are designing a new system called Distributed Energy Resource Management System, "DERMS" for both Power Potential and to complement future applications of ANM.

DERMS is a software-based solution that increases the DNO's real-time visibility of its underlying distributed asset capabilities. By collating network information and DER technical/commercial data, the DERMS will calculate the optimum DER production dispatch that satisfies the MVAr and MW services requested by NG ESO at the lowest cost. The DERMS platform will provide visibility of network availability and act on instructions provided via UKPN and NG ESO. The DERs will interface with the system via an on-site RTU and will receive signals to provide an increase or reduction in MW or MVAr, as needed.

As with the area under consideration in the SW Peninsula RDP, all new DER connections will include an ANM capability, so DERs will be obliged to accept some curtailment when the predetermined constraints are binding, with the level of curtailment dependent on the magnitude of the constraint.

[52] Regional Development Programme, South East Coast Regional Strategy Document Technical Report, National Grid and UK Power Networks, Mar. 29, 2019 https://www.nationalgrideso.com/document/140756/download

For this region, a pro-rata implementation is proposed under which blocks of capacity will be defined (quotas). For those generators within a capacity quota, curtailment is shared across all generators that are subject to a constraint proportionally to their contribution to the constraint.

A review of the process for developing balancing and system services has taken place to understand how this process could be better coordinated between NG ESO and DNOs to ensure that services developed by either party have a more optimum impact across the whole system. The recommendations from this work were fed into the Open Networks.

9.2.3 OPEN NETWORKS PROJECT, DSO SERVICES – CONFLICT, MANAGEMENT AND CO-OPTIMISATION[53]

Conflict between one or more services required by System Operators (SOs) may result in inefficiencies within the electricity system. This may be further compounded by conflicts between the capacity required to accommodate SO services and the capacity provided by Network Owners (NOs). Whilst service conflict is clearly a potential risk, there have been no measurable impacts to date and examples of conflict have been purely theoretical.

Conflict management describes the actions aimed at identifying and resolving conflicts in how specific assets are used to provide flexibility services. Conflicts can be identified across a number of different timescales depending on the procurement process and the data exchange refresh rate; from many years in advance, through to real-time. As many procurement processes are currently undertaken manually, the shortest time considered within this work is one week ahead. Conflicts can occur between different assets being used to manage different system constraints as well as conflicts occurring between services required and the ability of the network to accommodate those services.

Due to the way roles and responsibilities on the electricity system are distributed, and the differences in visibility created by traditional boundaries, then conflicts across different parties and actors are increasingly likely.

- More than one user of flexibility services trying to use the same asset at the same time (regardless of whether they want the same action).
- Different flex service users procuring/dispatching services on different assets that are electrically arranged so that one service negates or partially negates the other.
- DNOs ANM scheme reducing generation constriction (or load restriction on Load ANM scheme in the future) which negates the impact of a flexibility service procured/dispatched by a third party.
- A flex service user (other than DNO) procuring/dispatching a service that results in a capacity threshold being breached on the DNO network, and then causes the DNO to take action (may or may not be flex service) to avoid that threshold.

[53] Open Networks Project, DSO Services – Conflict Management and Co-optimisation, ENA, WS1A P5, Apr. 04 2020 https://www.energynetworks.org/assets/files/ONP-WS1A-P5%20Final%20Report-PUBLISHED.pdf

- A DNO procuring/dispatching a service that results in a capacity threshold being breached at the GSP and then causes NG ESO a problem.

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