ANM – Balancing Co-ordination Demonstration (ABCD)

Closedown Report

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Name	Role
Mazher Syed, WSP	Author
SGS	Author
Abdullah Emhemed, WSP	Author
David Penfold (SGC), Liza Troshka (NGED)	Reviewer
Jenny Woodruff	Approver

Contact Details

For further information please contact:

nged.innovation@nationalgrid.co.uk

Postal

Innovation Team
National Grid Electricity Distribution
Pegasus Business Park
Herald Way
Castle Donington
Derbyshire DE74 2TU

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Contents

1 Executive Summary

The potential for Active Network Management (ANM) systems and Balancing systems to negatively interact has been known for a long time. The previous joint NIA project between National Grid Electricity Distribution (NGED) and National Grid Electricity System Operator (NG ESO), Optimal Coordination of Active Network Management Schemes and Balancing Services Market[1], investigated the options to manage this conflict and modelled the impact of three shortlisted options. Two options related to improved forecasting of likelihood of curtailment which may require significant improvements to current forecasting capabilities before these can be implemented. The third option related to reconfiguring ANM systems to hold headroom to prevent counteraction when balancing service operations was instructed to customers within the area served by that ANM system. This option had not yet been fully specified or demonstrated and this project extended the previous work to modify an ANM system to include this functionality and test the operation under a range of conditions. The project was jointly funded with NG ESO with costs funded via Network Innovation Allowance (NIA).

Due to the risk, timescales and complexity of deploying an upgraded ANM system on the real network and the need to limit the project duration due to the end of the ED1 price control period (end of March 2023), the ANM system to be modified was tested offline. The operation of this system was tested with a range of operational scenarios and did not require real-time inputs/ outputs, but rather representative test data was provided. The outcomes of the offline testing provided useful learning from the operation of the system, and it would be possible to create a follow up project with a live trial.

The project, which ran from June 2022 to May 2023, developed algorithms for modified ANM operation to coordinate services which can be shared with other DNOs. Smart Grid Solutions (SGS) carried out the system modification and testing with WSP providing independent assessment of the performance. SGS and other ANM system developers can incorporate these changes into their ANM software. The project also specified the communications required to enable coordination between NG ESO and DNOs and the potential technical options to support such communications. Given the long timescales to implement Inter-Control Centre Communications Protocol (ICCP) links, and that such data is less critical for safe operation of the network, other options such as web services were explored. However, due to the lack of support for these protocols by control systems, the trial systems were implemented with ICCP.

Additionally, WSP investigated the likely financial and commercial impact under the new regulatory arrangements defined by the Access Significant Code Review (SCR) implemented at the start of ED2, the price control period starting in April 2023. A quantitative analysis was expected to be undertaken for which the data required had been identified. However, due to the lack of the availability of the required data to undertake the assessment, a qualitative assessment was undertaken instead. This assessed the degree to which the modified ANM system would result in generators being unable to release headroom and therefore in effect experiencing a higher degree of being constrained. It is recommended that the data identified in the commercial evaluation report e.g. annual curtailment limit per customer and their cumulative annual curtailment totals are collected by the ESO and DNO to allow evaluation of the financial impact of in the future.

The benefits of the project are the acceleration of the development of coordination functionality in ANM systems and the establishment of the basis for the key communication of enabling messages of responses. The benefits from the previous project of this type of coordination approach are in the region of £44m per annum across the UK reflecting savings in despatched balancing services but also gains from wider market participation which lowers prices overall. This project is expected to have annual benefits in the region of £70m across the UK.

The project has made great progress towards the coordination of ESO and DNO services that use Distributed Energy Resources (DER) and has demonstrated in a safe simulated environment how an ANM system can be programmed to maintain the impact of Balancing Services provided by DER at the Transmission / Distribution network interface. This included testing under a range of simulated scenarios. However, further work is required to develop and test ANM functionality and

[1] National Grid - Optimal Coordination of Active Network Management Schemes and Balancing Services Market

understand the impact on other services for business-as-usual application across all DNOs with the ESO which could be pursued in a subsequent project. The details of potential follow-up work are given in section 13 Planned Implementation.

2 Project Background

Potential conflicting operations between Balancing Services instructed by National Grid Electricity System Operator (NG ESO) and the Active Network Management (ANM) systems operated by Distribution Network Operators (DNOs) have been identified as a problem which can increase costs to the consumer and risk to security of supply if system services cannot be delivered when required.

The NIA project NIA_NGSO0035, Optimal Coordination of Active Network Management Schemes and Balancing Services Market, investigated the options to manage this conflict and modelled the impact of three shortlisted options. Two options relate to improved forecasting of the likelihood of curtailment which may require significant improvements to current forecasting capabilities before these can be implemented. The third option related to reconfiguring ANM systems to hold headroom to prevent counteraction when balancing service operations were instructed to customers within the area served by that ANM system. This was labelled as solution “W1”. It was anticipated that the solution would see a signal sent simultaneously to the generator and to the ANM scheme, requiring that the ANM scheme either:

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

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

The project also aimed to understand the potential monetary impact of operating a modified ANM system under different regulatory arrangements given the signals from Ofgem that they would be encouraging DNOs to pay for ANM customer constraints in the future. The SCR was published during the project timescales which laid out how future ANM connection arrangements are to be implemented in ED2. These were used to assess the likely cost impact to the DNO and the wider impact on costs from the change to ANM operation.

The project amended one ANM system, but the algorithms developed, and the specification of the additional communications were shared so that they can be adopted by other ANM systems. The modified ANM system was trialled using a test system, rather than a real ANM system to minimise the costs and risks of the project, but a wide range of operational scenarios were used to ensure that the modified system operates effectively. Similarly, the commercial assessment of the impact of changing the ANM system was designed to be indicative for all DNOs rather than specific to NGED.

3 Scope and Objectives

The scope of the project was the development of a proof-of-concept system supporting the shortlisted solution W1 (described in Section 2) and its demonstration within an offline test environment. The more specific objectives for ABCD are given in the table below.

Table 3-1: Status of project objectives

Objective	Status
Develop the detailed coordination process required to avoid counteraction of Balancing Services by maintaining the headroom on ANM systems and document this is sufficient detail so that it can be used by any ANM system provider to enhance their system.	✓
Understand and capture the data exchanges required to support the coordination process	✓
Modify an ANM system and test it using realistic scenarios to show how it would operate in a real-world implementation.	✓
Capture and share the project learning.	✓

4 Success Criteria

The success criteria for ABCD are given in the table below.

Table 4-1: Status of project success criteria

Success Criteria	Status
The detail behind the coordination methodology has been explored and expanded into a specification and a design solution which has been captured in the System Specification and Design document.	✓
The requirements of communications to support coordination have been evaluated and the data items, frequencies and underlying technologies have been specified	✓
A demonstration system has been built that can mimic the coordination process that would take place with live systems, and this has been used to test the process under a variety of realistic test scenarios.	✓
The learning from the project has been captured and disseminated.	✓

5 Details of the Work Carried Out

This project aimed to investigate how an ANM system operation could be modified to support co-ordination between DNO and NG ESO and delivery of balancing services. It included specifying the additional communications required between the ESO and DNO systems in order to support co-ordination. A demonstration / test system that could mimic real systems without the risk of affecting real customers was used to determine the performance and impact of the modified approach under a number of scenarios to show operation in a wide range of operational conditions. The project also included a commercial assessment of how this amended mode of operation would increase the degree to which customers were constrained and what the financial impact of that could potentially be with different potential regulatory arrangements in ED2.

The results from the trial and commercial analysis were then distilled for dissemination, with special focus on sharing relevant learning to the Open Networks project that are looking at Primacy Rules.

This was achieved through a series of work packages that are described below.

5.1 WP1. Specification & Design

This work package, involving all partners, specified the processes and technologies by which

- the notifications from NG ESO will be shared with DNOs[2],
- the DNO will process the request (including checking for co-ordination with any other DNO planned actions e.g., flexibility services - DSO Primacy rules) and relay the information to the relevant ANM system, and
- the ANM system operation will be modified.

The specification of the system requirements therefore covers both the modifications to the ANM system (and any other related system such as PowerOn) as well as the new communications and supporting technology. It involved two cross party workshops and particular attention was given to the cybersecurity requirements. The results were recorded in Deliverable WP1 D1 – The System Specification and Design document.

Once the system requirements and design were known, this was then used to specify the Factory Acceptance Testing requirements. These are documented in Deliverable WP1 D2 - Factory Acceptance Test Workbook

Finally, the scenarios and tests required to be carried out during the trial and the datasets that are required to support the trial were determined and documented in WP1 D3 – the System Trial Plan. This also detailed how the system needs to be configured, who will carry out each test, the process for witnessing tests etc.

Deliverables

Deliverable WP1 D1 - System Specification & Design document

Deliverable WP1 D2 – Factory Acceptance Test Workbook

Deliverable WP1 D3 – System Trial plan

5.2 WP2 Commercial Evaluation

This work package, delivered by WSP, assessed the potential financial implication of extending the degree to which ANM customers are constrained by altering the operation of ANM systems. The analysis reflected the regulatory changes resulting from the Access SCR that offers a new type of ANM connection agreement for those connecting during ED2. While previous ANM customers received no compensation for their curtailment, ANM customers in ED2 will benefit from a cap on the degree to which they can be constrained annually after which compensation payments become payable for constraints on the distribution system. This analysis was therefore

[2] How these requests will be co-ordinated with other NG ESO service requests is out of scope as this is covered by the work on ESO Primacy Rules.

complex as any payment due would be highly situationally specific e.g. it would only apply to ANM customers that connected in ED2, only after the cap was reached and even then only if the constraint were on the distribution system as Transmission constraints were exempt.

As well as outlining the potential costs to DNOs, the whole system costs were assessed in order to confirm that the changes did not undermine the business case for implementing the modifications to the ANM systems.

The outcomes of the work package are documented within Deliverable WP2 D1 – Commercial Evaluation Report.

Deliverables

WP2 D1 – Commercial Evaluation Report

5.3 WP3 System Development

This work package, delivered by SGS, involved the development of the modified test ANM system. This included:

- Provision at Test Environment in Amazon Web Services (AWS) (Strata Grid + a version of Strata that looks like PowerOn (with an ICCP link).
- Configuring the schemes to operate as defined in the specification given in WP1 which requires a certain level of headroom to be “held” when balancing actions are instructed.
- Configuring the Restful Application Programming Interface API that can be used to simulate a link with NG ESO for the relevant parts of the process from WP1 D1.
- Implementing a test harness that supports testing defined in WP1 D2 and WP3 D3.

Deliverables

The deliverable for this work package is the completed system development, however the acceptance criteria for this deliverable is given in WP4 so this is recorded in WP4.

5.4 WP4 System Factory Acceptance Testing (FAT)

The set of tests to confirm the operation of the system meets the specification were carried out by SGS and witnessed by the other partners using the workbook delivered in Deliverable WP1 D2 to record the results of the tests. This work package included rework required to ensure all the tests in the workbook are successfully signed off. The results are documented in Deliverable WP4 D1 – Completed FAT Workbook

Deliverables

WP4 D1 – Completed FAT Workbook

5.5 WP5 System Trial

This work package involved the testing of the operation of the coordination solution with simulated balancing system requests under different conditions. This was carried out by SGS and WSP according to the agreed System Trial plan, Deliverable WP1 D3.

Deliverables

WP5D1 – System Trial Results Report which documents the results of the agreed system trial plan.

5.6 WP6 Evaluation & Dissemination

This work package, delivered primarily by WSP with input from the other partners, included an assessment of the performance of the system during the trial, distilling and disseminating the project learning.

Communication and dissemination are crucial activities to ensure the widespread and timely transfer of project outcomes to the target audience and to engage them in activities of the project. To this end, a dissemination plan was developed, identifying the target audience and activities with associated timelines.

The communication with the target audience and the dissemination of the project value to them is of particularly high importance for NIA projects. It is important to establish communication and dissemination in such a way that they reach the end users in the most efficient and engaging way. A list of relevant target groups identified is presented below:

- National Grid ESO
- GB Distribution Network Operators
- ANM System Developers
- Research and Academia
- Public

The activities developed and delivered to support the communication and dissemination of the project outcomes are summarised below.

Press Release

A short overview of the project, highlighting the key issues addressed and the perceived added value to the public was published in the form of a press release. This forms an effective way of reaching broader audience as has been utilised by several NIA projects in the past. The press release was handled by NGED.

Closedown Report

This closedown report serves as a summarised document of the project, documenting the challenge, the approach to address the challenge and the obtained results. It summarises the learnings from the project and the outcomes of the project and details a plan for its implementation.

Project Webinar

The findings of the project were disseminated though a public webinar in May 2023 as the project came to its end. The key challenges of coordination between ANM services and balancing mechanisms were articulated followed by the technical solutions considered within the project. The solution chosen for demonstration was elaborated with detailed results and analysis presented and discussed.

LinkedIn platform was utilised to reach all the target groups identified. Announcement of the webinar was publicised on LinkedIn in addition to targeted emails by NGED to relevant stakeholders. The recorded webinar of the project and slides are available for public access on NGED Innovation website.[3]

Deliverables

WP6D1 – Learning and Closedown report - this captures the project learning and evaluates the project providing the information required to complete a project closedown report.

WP6D2 – Dissemination materials – these are the slides / videos etc. used for the project dissemination webinar.

[3] https://www.nationalgrid.co.uk/innovation/projects/anm-balancing-coordination-demonstration-abcd

6 Performance Compared to Original Aims, Objectives and Success Criteria

The performance of the project against the original objectives is summarised in the table below:

Table 6-1: Performance compared to objectives

Objective	Status	Performance
Develop the detailed coordination process required to avoid counteraction of Balancing Services by maintaining the headroom on ANM systems and document this is sufficient detail so that it can be used by any ANM system provider to enhance their system.	Complete	A coordination process was developed and findings documented in this report with signposts to the key documents developed during the course of the project.
Understand and capture the data exchanges required to support the coordination process	Complete	Simulation systems were used to validate the data exchanges.
Modify an ANM system and test it using realistic scenarios to show how it would operate in a real-world implementation.	Complete	A demonstration system was built in AWS based on SGS products (WP3 - System Development complete)
Consolidate and share the learning from the project	Complete	The learning from the project has been captured in this closedown report. A dissemination webinar was held in May 2023.

The performance of the project against the original success criteria is summarised in the table below:

Table 6-2: Performance compared to success criteria

Success Criteria	Achieved	Performance
The detail behind the coordination methodology has been explored and expanded into a specification and a design solution which has been captured in the System Specification and Design document.	✓	This was captured as part of WP1 D1 - System Specification & Design document
The requirements of communications to support coordination have been evaluated and the data items, frequencies and underlying technologies have been specified	✓	This was captured as part of WP1 D1 - System Specification & Design document
A demonstration system has been built that can mimic the coordination process that would take place with live systems, and this has been used to test the process under a variety of realistic test scenarios.	✓	A Demonstration system was built in AWS (WP3 - System Development complete)
The learning from the project has been captured and disseminated.	✓	The learning from the project has been captured in this closedown report, which will be published. A dissemination webinar was held in May 2023.

7 Required Modifications to the Planned Approach during the Course of the Project

There were several minor modifications to approach that took place during the project.

The work within the commercial evaluation work package was originally expected to have a wider scope, however it was found that key items of data that were required for a full financial analysis were unavailable. Therefore, the commercial evaluation report included more qualitative analysis and less quantitative analysis than had been originally anticipated.

The original intent was to have separate stages for Factory Acceptance Test (FAT) and scenario testing but as the project progressed it was determined to be more beneficial to carry these out simultaneously.

The original modifications to the system were found to operate incorrectly, causing additional unwanted curtailment. This required a revision to the system.

A change in staff roles within NGED resulted in bringing in additional project management resource from Smart Grid Consultancy.

There were small scale delays that resulted in an extension to the project timescales to complete in May rather than at the end of March.

All modifications to the project approach were assessed for materiality and impact using the normal project governance process.

8 Project Costs

A summary of the project costs is presented in table below.

Table 8-1: Project Spend

	Budget (£)	Actual (£)	Variance (£)
SGS	139,820	139,820	0
WSP	76,669	76,669	0
NGED Project Management	24,325	35,510	-11,185
NG ESO Project Management	24,325	24,325	0
Total before Contingency	265,139	276,324	-11,185
Contingency	26,513	11,185 (included in actuals above)	15,328
Project Total	**291,653**	**283,242**	**15,328**

The project spend is within the overall budget. Project management costs for NGED are overspent due to staff changes in the innovation team which required an external project management resource to be used. The costs of this are covered by the project contingency.

9 Lessons Learnt for Future Projects

A summary of the key learning points is given below. Further details of the learning were included in the dissemination event.

9.1 Data Quality and Availability

The project had hoped to use data that was not normally used within the business for the commercial evaluation report. The lack of certain data items and the difficulty in determining the context for any customer constraint periods became apparent as the work progressed. The project learned that the following data items were not available:

- Historic levels of headroom created by the ESO's balancing service decrement requests
- Historic export prices
- Historic levels of curtailment
- Flexibility procurement prices
- Exceeded Capacity Price

Similarly the curtailable load and position in the LIFO stack for each relevant generator was more difficult to obtain than was anticipated. It is expected that some of this data will be collected in the future to meet the Access SCR changes.

9.2 Specification & Design

Data Mapping: During the implementation a potential complexity around data mapping was identified where the unique identifiers for generation and load assets used by the ESO would likely differ from those used by the DNO. As such a mapping layer would need to be implemented somewhere on the system, initial designs discussed an independent "Data Platform" which could be a suitable place for this mapping to occur.

Signal Exchange: There was difficulty around the mechanism of communicating Bid Offer Acceptance Instruction (BOAi) / Physical Notification (PN) between ESO & DSO – operational protocols such as ICCP make this type of data transfer difficult. The use of web services to exchange data was explored, however, early in the design stage it was clear that the required information wasn't available through web services in neither the ESO nor the DNO operational environments. For purpose of demonstration, ICCP conformance block 4 (InformationMessages) was used to transmit messages in text format but this block is not widely supported / utilised in control systems and as such may not be practical in an operational context.

9.3 Deployment & Test

Due to time constraints the Factory Acceptance Tests were not witnessed by the wider project team. It would have benefited the project to have had representation from all partners witness Factory Acceptance Testing. The project had many nuances, and the documented test script alone was not a substitute for the project team to having the opportunity to see SGS's product "in action" and ask questions to the SMEs.

9.4 Trial

Service Degradation Due to Ramping: Some degradation of ESO service due to Balancing Mechanism Unit (BMU) ramp down occurring before the hold mode ends. The system implementing the hold mode ideally should initiate hold mode when the BMU starts ramp down, not at the BOA start time, but this requires knowledge of BMU ramp rate / start time. Two solutions are possible for this:

• Exchange a larger volume of information such as generator ramp rate and expected start time. The ESO holds operational data for each registered BMU including ramp up and ramp down within the Balancing Mechanism (BM) system. When the BM instructs a BMU to be at a set power level at a specified time the BOA instruction issued by the ESO has accounted for the BMUs power ramp rates.

• If the only information exchanged is a binary on/off hold mode signal then it must be applied at start of generator ramp down. This may have further implications on other methods of solving this conflict of services.

Reduction of Curtailment Events: Hold mode can help reduce control actions on ANM controlled Distributed Generation (DG) when an embedded BMU ramps up after providing a BM service.

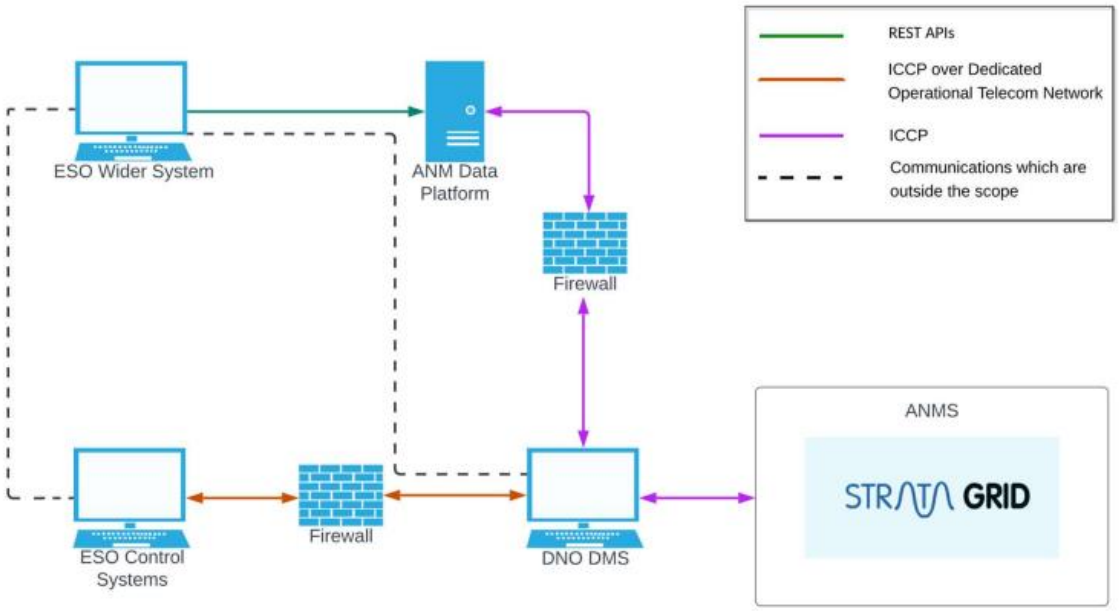
10 The Outcomes of the Project

The outcomes of the project are summarised in the following two subsections.

10.1 Development of Coordinated Solution to Mitigate Conflict between Balancing and ANM Services

The diagram below shows a high-level overview of the solution. This shows the different systems which contribute to the solution and how they interact. The solution shown aims to provide a unified method of exchanging data to allow both the ESO and DNO to make effective decisions on resources to use to ensure the efficient operation of the network. The different systems represented are:

- DNO DMS: The DNO's Distribution Management System (DMS) is responsible for the overall management and control of the distribution network.
- ESO System: This is an enterprise level ESO system which exchanges data with the ANM Data platform to ensure that both the ESO and DNO have enough information to co-ordinate service acquisition.
- ESO Control System: The ESO Control System manages the UK wide electricity transmission system collecting data and managing assets connected to it.
- ANMS: The ANMS is responsible for actively controlling DER on the distribution network
- ANM Data Platform: The ANM Data Platform provides an individual location for data relevant to Balancing Co-ordination.



Conflict arises when both the ESO and DNO are managing DER embedded in the distribution network in a way which nullifies the other party's actions. For example, the ESO may request that a DER performs generation turn-down which allows the DNO's ANMS to remove export limits on other DER; this could partly nullify the ESO's action. This conflict can be managed by the DNO by placing the ANMS into an alternate mode of operation (Hold Mode) that prevents the release of constrained export from ANMS connected generators where this would degrade the ESO generation export turn down service instructed.

This is achieved through autonomous signalling between systems to manage dispatch of services and for the exchange of data to all parties to pre-emptively understand what services are scheduled that are likely to cause conflict.

A high-level overview of the process is described below:

- A notification from ESO is shared with DNO to inform that a service is being used.
- The DNO processes the information and notifies the ANMS, then the ANMS operations are updated.
- SGS's conflict resolution solution (Hold Signal) ensures that ESO and DNO service conflicts are managed and that each can be used to the fullest effect possible while maintaining Primacy rules.

10.2 Proof of Concept Solution Demonstration

The Trial was completed through scenario driven tests, which validates the ANMS operation during the ESO and ANM service conflicts. The input data consists of various power system parameter values (e.g., real power, voltage), which were input into the simulation systems to represent various scenarios.

20 scenarios were tested under the following categories:

1. Service Conflicts: Demonstrating conflict of services where the ANM degrades the ESO request.
2. ESO Decrementing Service Requests: Demonstrating successful resolution of conflict
3. Management of Boundary Export: Demonstrating management of conflict & continued management of conflict during the duration of ESO service requests.
4. Constraint Management: Demonstrating successful resolution of conflict under when different constraints are active.
5. Response to Failures: Demonstration resolution of conflict under different failure scenarios.
6. Principle of Access: Demonstrating resolution of conflict under different ANM principles of access.

Full details of the results were documented in WP5D1 – System Trial Results Report.

The subsections below provide an overview of two scenarios:

- Service Conflict – Non ANM Generator: Where no coordination is enabled, and conflict is observed.
- ESO Decrementing Service Requests with two Non-ANM generators being subject to a BOAi request: where coordination is enabled, and conflict is resolved.

10.2.1 Service Conflict – Non ANM Generator

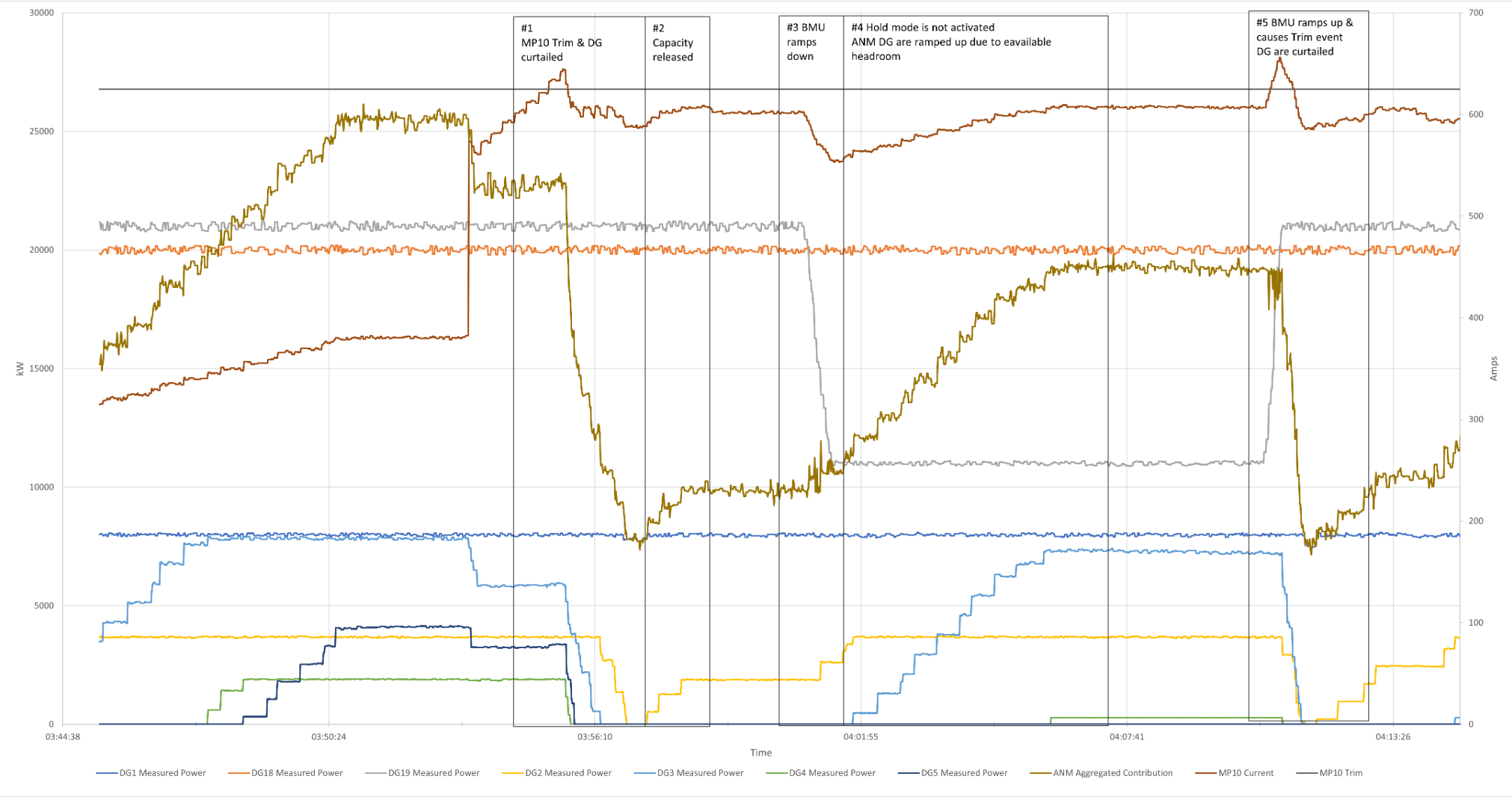


Figure 1: Scenario C1 results

10.2.1.1 Detailed Review

This scenario demonstrates the current state of play where no signals are passed between ESO and DNO and as such the ANM hold mode is not activated and ANM generators are allowed to increase their export when ESO instructed generators are providing generation turndown services – it is expected that it would be possible to see the detriment of ESO services.

Detailed steps as highlighted on Figure 2 Scenario C1 results:

1. Current on MP10 increases and breaches its Trim Threshold just prior to the time of 03:56 and DGs are curtailed in LIFO order: DG5 to DG 2 issued 0MW setpoints by the ANM.
2. DG2 released as there is a small amount headroom is available between MP10 measured value and trim threshold.
3. In response to a BOAi Non ANM controlled generator DG19 output is reduced from 20 MW to 11 MW.
4. Hold Mode is not activated and as such the ANM system observes the extra headroom and allows DG2, 3 & DG 4 to some extent to increase their export while DG5 remains curtailed in accordance with the ANM LIFO priority stack.
5. BOAi end time is reached and DG19 ramps up to previous operating level – this causes the distribution constraint MP10 to breach its Trim threshold causing further curtailment to ANM DG2, 3 and 4.

It is important to observe the "*ANM Aggregated Contribution*" in this graph is not maintained at a static level during the Balancing Service request – instead it increases to the detriment of the Balancing Service. This demonstrates the issue of not employing an ANM hold mode to maintain BM instructed export reduction services, the rise in the "ANM aggregated Contribution" is reflected at MP 10 and would be reflected at the Transmission/Distribution network interface showing an erosion of the BM export reduction service instructed.

10.2.1.2 Analysis

In this scenario DG19 is also associated with the distribution constraint and as such its ramp up after providing services is shown to cause trim breach on distribution constraint. This raises the possibility that when the ANM system has awareness of ESO services then the number of curtailment instances can be reduced.

Similar results can be seen in "*C2- Service Conflict – ANM Generator managed against SGT reverse power flow constraint & ESO request*" where the balancing service is provided by an ANM controlled generator.

10.2.2 ESO Decrementing Service Requests with two Non-ANM generators are subject to a BOAi request.

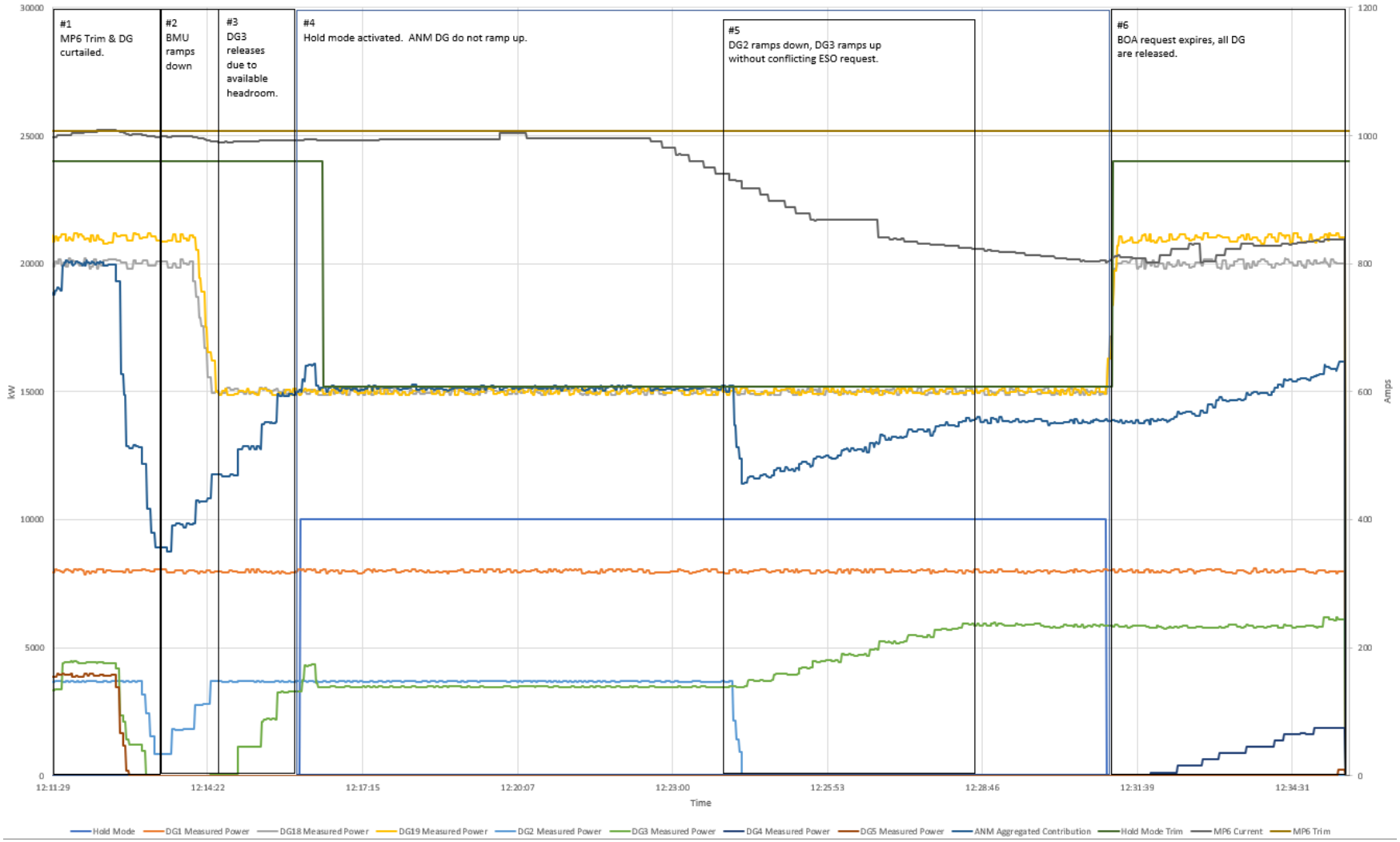


Figure 2: Scenario C5 results

10.2.2.1 Detailed Review

This scenario demonstrates the effectiveness of the Hold Mode in preventing ANM generators from increasing their export when other generators are providing ESO BM instructed generation turndown services.

Detailed Steps:

1. Current on Transmission constraint MP6 increases and breaches its Trim Threshold.
    a. DG are curtailed in Last In First Out (LIFO) order: DG5 to DG2 are curtailed.
2. In response to a BOAi, the outputs of non-ANM controlled generators DG18 and DG19 are reduced from 20MW and 21MW respectively to 15MW each.
3. Due to ramp down of the BMU, ANM observes some capacity was given to DG2 & 3 before hold mode enacted.
4. The ANM System enters hold mode & blocks all ANM controlled DER from releasing above the initial ANM aggregated export level prior to the hold mode enabling.
5. Part way through the BM export reduction service, DG2 stops exporting, this allows the ANM to release additional capacity to DG3 without conflicting with the ESO BM instructed request.
6. The BOAi expires, hold mode is disabled and DG begin to release according to LIFO Principles of Access (PoA), DG4 can be seen raising its export.

It is important to observe the "*ANM Aggregated Contribution*" in this graph maintains a consistent upper limit during the Balancing Service request which is not exceeded (the exception being right at the start of the Hold Mode where DG3 is already in the process of ramping up export and is then trimmed back to meet the ANM aggregated hold mode limit).

10.2.2.2 Observations

This scenario test demonstrates some erosion of ESO service due to the time it takes for BMUs to ramp down before the BOAi starts / Hold mode is enabled – in this scenario it resulted in ~4MW of erosion although the volume is completely dependent on BMU ramp rates and ANM system response times. Similar results are observed with C3, C4 & C6 - C8 where hold mode is demonstrated to resolve conflict across different BOAi scenarios:

- Non-ANM generator by itself,
- ANM generator by itself,
- Two non—ANM generators,
- ANM and non-ANM generators with concurrent / sequential / overlapping requests.

10.3 Selected Questions & Answers from the Dissemination Webinar

This section presents a selected list of questions and answers from the dissemination webinar held on the 11th of May 2023.

Question: In Hold Mode, what are the potential commercial or contractual implications for generators that are curtailed and are connected under flexible connection agreement?

Answer: It is anticipated that there will be a commercial and contractual implication. The project was unable to evaluate the impact quantitatively due to the lack of data that has been highlighted. This has been identified as future work.

Question: Are you designing and delivering an automated method of sending ESO service information to DNO as opposed to DNO logging on to ESO portal to manually extract the data.

Answer: Yes, it is designed to operate autonomously, enabling automated data exchange.

Question: You have indicated that ICCP wasn't suitable for passing instructions and showed an idealised architecture. However, you implemented the instructions via ICCP, please explain the unsuitability ICCP vs the systems that do not exist.

Answer: ICCP information exchange block that allows text-based messages was utilised. This block is not widely utilised and therefore maintained. It is also questionable as to how many control systems use it. Significant infrastructural changes will be required to the existing ANM and control systems to enable the use of ICCP for this particular purpose, though ICCP links are in place for other uses.

Question: On grid supply points with multiple users, how is it determined which users the signal is passed to?

Answer: Assuming multiple users refers to multiple flexible DERs within the network, the instruction is passed to ANM itself and the ANM decides according to the control order it determines.

Question: Does DER refer to distributed generation and demand response?

Answer: For this trial, only distributed generation has been considered. There can be other conflicting situations where demand response could be utilized.

Question: Have you considered the impact of DER communication system failure on constraint management? For example, cell phone network outage or during cold start or system restoration?

Answer: Some of the scenarios looked at included failure scenarios, mostly a subset of communications system failures or a subset of ANM system failures. Complete system failure, communications or ANM, was out of scope and therefore not investigated. It is assumed that such a scenario will be covered by existing failsafe mechanisms.

Question: Have you considered the possibility of service stacking where the DER provides some services to the DNO and another service to ESO?

Answer: It is envisaged that the coordination for service stacking is managed by the service provider themselves.

Question: Was the only consideration generation reduction, is it not envisaged that BM participants might be able to offer increase in generation in a network area covered by ANM?

Answer: It is possible for BM participants to offer increase in generation but was not a conflict looked at within this trial. There might be a potential conflict and is something that can be investigated in the future.

Question: What about of ANM systems that cover wide range of distribution network constraints on the 132/33 kV distribution network, any curtailment is applied based on generator contribution to a given network constraint rather than purely LIFO, it seems the concept of Hold Mode wouldn't work as described for these systems.

Answer: The scenarios that we looked at were fairly high level and included the assets at the voltage level in question. We were able to demonstrate that the Hold Mode can control and manage the conflict.

Question: How is the HOLD mode enabled, is this automatic following ESO service request or it needs to be manually enabled on the ANM system?

Answer: Hold Mode is enabled automatically.

Question: Does the Hold Mode hold all existing trim thresholds, or does it hold generators under ANM control at the level they were actually exporting when it was enabled.

Answer: It controls at the level they were exporting when hold mode was enabled but there is flexibility when hold mode is enabled for that capacity to be shared following the LIFO ordering or whichever priority of access is defined.

11 Data Access Details

No new data was captured as part of the project.
Key information about the project is available on NGED's Innovation website[4] or upon submitting a request on NGED.Innovation@nationgrid.co.uk.

[4] National Grid - ANM - Balancing Coordination Demonstration (ABCD)

12 Foreground IPR

New IPR was generated in terms of the algorithms applied in the future modified systems and the specification of the communications link. This IPR is owned jointly by all four partners each having a 25% share. The IPR associated with the modified code and software developed by SGS is owned entirely by SGS.

13 Planned Implementation

The project successfully developed the proof-of-concept implementation of the solution W1 that facilitates the coordination between Balancing Services activation and ANM services to avoid potential conflict. The mitigation of the conflict was successfully demonstrated within an offline test environment. All care and due diligence have been undertaken to ensure the developed solutions can be implemented in real-world, ensuring the protocols used for communication, cyber-security implications and ensuring generalisation for implementation within networks of all DNOs.

Work remains to be undertaken for the deployment of the proposed solution within the field, the technology readiness level of the solution needs to be further appraised. The consortium is currently in discussion and preparing a potential application to Strategic Innovation Fund to enable the development of the product and consequent implementation within a distribution network for field trial.

The steps towards full Business as Usual roll out could include the following items.

1. Hardware-in-the-loop testing including some of the scenarios tested in the project simulated environment. It is proposed to reduce the areas of simulation and replace with real systems where possible as an intermediary step to a full system test.

2. Full live system testing on a selected area of network with DER providing ESO balancing services within a DNO ANM managed zone. Again, this would include testing some of the scenarios tested in the project simulated environment.

3. Extending the ANM functionality in the project which covered Balancing Services export decrementing to include export and import incrementing and import decrementing.

4. Extending the ANM functionality tested in the project to include other ESO Services such as Transmission Constraint Management (TCM) or Short-Term Operating Reserve (STOR) which use DER.

5. The project architecture for the coordination of ESO and DNO services introduced the idea of the ANM Data Platform. The ANM Data Platform is a new component which aims to provide a single location for data relevant to service co-ordination. This provides flexibility when considering the extension of the system to exchange a wider set of data allowing both ESO and DNO to plan service dispatch to reduce the chances of conflict. Much of this data is not suitable for the operational communication channels currently used to exchange data between ESO and DNO. Work to prepare for Business as Usual implementation could develop a meaningful function for this platform e.g., allow the DNO to place weekly forecasting of flexibility service dispatching to assist the ESO with dispatching of its own services. Consideration could be given to the ESO to ANM Data Platform interface and a test and trial plan developed taking the ANM Data Platform from a simulated test to some form of hardware-in-the-loop testing.

It is recognised that development of the ANM Data Platform is dependent on areas of ESO/ DNO system development and areas such as the ENA Primacy Rules project and hence may be some years away from becoming a reality. However, it is thought that the concept of the ANM Data Platform is worth exploring further and agreeing at least one useful function that could be trialled to help the ESO and DNO coordinate services from DER. This could be the provision of embedded BMU ramp rates to improve hold mode performance.

6. “Service Degradation Due to Ramping” could be further investigated, where a number of methods for reducing degradation could be explored, such as:

- Tuning of the control algorithm to act faster,
- Transferring a richer data set to inform the Hold Mode calculation.

The application of these methods could result in less degradation of the ESO Service, and a reduction in curtailment.

14 Contact

Further details on this project can be made available from the following points of contact:

nged.innovation@**nationalgrid.co.uk**

Innovation Team

National Grid
Pegasus Business Park,
Herald Way,
Castle Donington,
Derbyshire
DE74 2TU

15 Glossary

Abbreviation	Term
Access SCR	Access Strategic Code Review
ANM /ANMS	Active Network Management / System
API	Application Programming Interface
AWS	Amazon Web Services
BM	Balancing Mechanism
BMU	Balancing Mechanism Unit
BOAi	Balance Offer Acceptance Instruction
DER	Distributed Energy Resources
DG	Distributed Generation
DMS	Distribution Management System
DNO	Distribution Network Operator
DSO	Distribution System Operator
ENA	Energy Networks Association
FAT	Factory Acceptance Test
HV	High Voltage
ICCP	Inter Control-room Communications Protocol
LIFO	Last In First Out
NGED	National Grid Electricity Distribution
NG ESO	National Grid Electricity System Operator
PN	Physical Notification
PoA	Principles of Access
SAT	Site Acceptance Test
SGC	Smart Grid Consultancy
SGS	Smarter grid Solutions
STOR	Short Term Operating Reserve
TCM	Transmission Constraint Management
WP	Work Package

Registered Office: Avonbank, Feeder Road, Bristol BS2 0TB
nationalgrid.co.uk