Project FUSION

FUSION Interim Trial Learnings Report

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SCOTTISHPOWER

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Executive Summary

INTRODUCTION

Project FUSION has prepared this document to report on the progress and the intermediate learnings from phase 1 and 2 of the FUSION trial which commenced on 09th Sep 2021, as well as to communicate next steps.

This document should be read in conjunction with other FUSION publications and particularly the FUSION' Interim Trial Learnings Report #1, published in October 2021 and FUSION' Interim Trial Learnings Report #2, published in May 2022.[1]

OVERALL TRIAL LEARNINGS [2]

The FUSION trial has been operational since September 2021, and flexibility is being dispatched in both St. Andrews and Leuchars areas. In Phase 1 and 2 of the trial, network congestion events are simulated almost daily to allow the trials to respond to those events using flexibility.

Phase 2 of the FUSION trial started in April 2022 and has seen the addition of three 11kV feeders as congestion points in the trial to add to the two primary substations. The following statistics provide a snapshot of progress in Phase 2 and across the full trial period (at the time of writing):

- 446 FlexRequests have been issued by the DSO including 235 in Phase 2;
- Power in the FlexRequests ranged from 0.4-1000kW with a median of 200kW;
- 575 FlexOffers responded to these requests including 307 in Phase 2
- The average offer price was £0.59/kWh in Phase 2 compared with £0.46/kWh in Phase 1;
- 43 MWh of flexible energy has been ordered and 32.1 MWh has been delivered; and
- Total utilisation payments amounted to £18,309 including £11,200 in Phase 2.

The trial showed that:

- Aggregators were able to respond to FlexRequests with at least one offer in 93% of cases.
- Aggregators were able to deliver 70% of the ordered flexibility, with one aggregator averaging 86%.
- Phase 2 saw an increase in the frequency of free bids with prices set above the cap for non-free bids. 31% of FlexOffers were above this cap.
- In Phase 2, aggregators continued to be more likely to overdeliver power than under-deliver despite changes to the FSA to reduce the penalties for underdelivery. On average. aggregators realised 143% of the ordered power (i.e. if flexibility delivered is not capped at 100% of a FlexOrder). Aggregators advised that they are still conservatively approaching the delivery of flexibility by dispatching more assets than are needed to cover the FlexOrder power.

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[1] https://www.spenergynetworks.co.uk/pages/fusion.aspx#tablist1-tab4

[2] Please refer to Section 3 for further detail

- The aggregators have been most conservative by activating more flexibility when dispatching a smaller number of assets at the 11kV feeders. This conservatism is to ensure that they achieve at least the ordered flexibility and is demonstrated most clearly at the 11kV "18612", which has the highest over-delivery of all congestion points
- The accuracy of the aggregator's baseline has impacted the results for the reliability of delivery particularly for one of the aggregators at St Andrews. This is evidenced by large negative deliveries (i.e. increasing demand or reducing generation) after a FlexOrder for positive delivery is sent, particularly during the month of June.

TRIAL LEARNINGS PER OBJECTIVE [3]

Project FUSION partners agreed on a set of learning objectives for the FUSION trial. The following provides a status update on the progress to date against each objective:

Common Reference Operator

The Common Reference Operator (CRO) is responsible for operating the common reference (CR), the repository that contains detailed information on network congestion points, associated connections, and active aggregators in those connection points. The CR enhances transparency by allowing aggregators to get the information on the congestion points where they are active (and only those for confidentiality and privacy reasons). It also allows DSOs to get visibility on the aggregators operational at their congestion points.

The experience of both SP Energy Networks, fulfilling the Common Reference Operator role, as of the aggregators as users has been positive, as it facilitates access to the information. Aggregators highly appreciate the security of the platform and encryption. In addition, maintaining the CR at DSO level is considered beneficial, further coordinating with ESO requests potentially unlocking value stacking opportunities.

Refer to section 4.1 of this report for full analysis of this objective.

DSO Data Transparency

The FUSION project explored the data transparency of the processes and the experience of the trial participants. It was confirmed that aggregators and the DSO did not have notable issues accessing or sharing data in the FUSION trial.

Furthermore, the FUSION trial participants are not facing data privacy concerns. Nonetheless, if the CRO role were to be transferred from SP Energy Networks to a separate entity, a thorough due diligence process would have to take place to ensure the data is stored, handled and processed appropriately.

From the two competitive processes with which aggregators can offer flexibility to the DSO, aggregators found availability contracts transparent, however, had questions regarding the selection of utilisation bids for certain lesser common cases that will be clarified for the next phase of the project.

Refer to section 4.2 of this report for full analysis of this objective.

Free Bids

USEF defines free bids as flex offers which aggregators send in response to a flex request from the DSO, that are either outside of their contracted availability window or above their contracted power capacity. This objective aims to analyse aggregators' experience with this mechanism; and whether

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[3] Please refer to Section 4 for further detail

the use of free bids would save costs for DSO and benefit the aggregator by allowing them to bring additional non-firm capacity to the market (e.g. residential).

- Free bidding is, according to the aggregators, a mechanism that will contribute to making more flexibility available and positively impact their business case by enabling additional revenue on non-firm capacity and value stacking in the future.
- Raising the free bids price cap in phase 2 had a positive effect in raising public interest (from aggregator's customers) on flexibility and is a good incentive to encourage participation.
- The current contractual arrangements and payment structure do not make free bids of primary importance aggregators. While aggregators appreciate the mechanism as extra revenue source, their focus is to fulfil their obligations on availability and get the payment through the availability contract.
- To participate in free bids, the aggregator needs to have short-term flexibility monitoring capabilities.
- The DSO saved 64% of the contracted capacity thanks to the extra capacity made available by the aggregator outside the availability contract (i.e. free bids).
- Even considering the potential savings, the DSO would only consider relying on free bids if there is sufficient market liquidity to make that approach statistically reliable, which is highly dependent on location for congestion management services.
- Ultimately, the trial has shown that the free bidding concept works but the current market and system is not mature enough yet to fully leverage this mechanism.

Refer to section 4.3 of this report for full analysis of this objective.

Baseline design

D-programme (or D-prognosis) is a forecast that the aggregator provides day-ahead to the DSO, this forecast contains the net load or generation of each aggregator portfolio per congestion point. This forecast is submitted before flexibility trading, which means that it does not include DSO service delivery. USEF designed D-programmes for two purposes – 1) serving as baseline to quantify flexibility delivery and 2) providing visibility to the DSO for their own forecast as well as having the visibility on the flexibility amount that they could request from aggregators. In this report, we have analysed the effectiveness of D-programmes in satisfying the baseline use case through quantitative analysis and insights from FUSION trial participants and the DSO.

Regarding the use of D-programmes as aggregator baselines:

- In Phase 2, aggregators have been capitalising on the opportunity that nomination baselines offer to trial different baseline methodologies to improve the accuracy of their forecasting.
- In Phase 2, the overall accuracy of the D-programmes has continued to be relatively poor when compared to what is typically regarded as a "good" or "acceptable" baseline[4]. It is worth noting the portfolios are relatively small, which makes them generally more difficult to forecast than larger, more diverse portfolios.
- We compared the accuracy and bias of the baselines in the trial with the ENA's online historical baseline tool and found that ENA's tool was more accurate and had less bias. Nevertheless, the historical baseline is still also not able to achieve a baseline accuracy that is considered "acceptable" at all congestion points except one.
- All parties involved recognise the need to monitor the baseline as a key first step to improve the baseline. The next steps are therefore to explore alternatives for monitoring

[4] This definition and criteria is based on the report "Baselining the ARENA-AEMO Demand Response RERT Trial" https://arena.gov.au/assets/2019/09/baselining-arena-aemo-demand-response-rert-trial.pdf

responsibilities and potentially add a clause in the FSA. It is also recommended that all aggregators provide daily meter data for all days including non-event moments so that the baseline accuracy can be calculated without the need to request supplementary information.

Refer to section 4.4 of this report for full analysis of this objective.

Market Co-ordination Mechanism (MCM)

The USEF MCM facilitates flexibility trading and consists of five phases – contract, plan, validate, operate and settle. During the trial, the contract phase was populated at the procurement stage whereas the phases from 'plan' to 'operate' were conducted day-ahead and intraday. This report analyses:

1. the *experience* of aggregators using MCM features such as FlexReservationUpdates and D-programmes intraday updates;
2. the *reliability* impact of MCM
3. the efficiency impact of MCM linked to DSO forecast accuracy
4. The conclusions are based on quantitative analysis of trial data and feedback from the trial participants and DSO insights:
    - Aggregators consider the MCM useful, clear and well structured, as they benefit from the whole process being defined in a single system, avoiding the need to use several systems across different phases.
    - Trial participants made suggestions for improvement on contract timing aspects (e.g. aggregators suggested to have week-ahead availability contracts) and bid selection (e.g. the DSO suggested the inclusion of carbon emissions information).
    - MCM has a positive impact on reliability - between 1-28% increase - compared to other DSO flexibility trials.
    - MCM has a positive impact on efficiency linked to DSO forecast accuracy. Because of its shorter procurement and dispatch timeframes, USEF allows a 1-3% reduction of DSO flexibility needs to account for forecast inaccuracy.

Refer to section 4.5 of this report for full analysis of this objective.

USEF Flexibility Trading Protocol (UFTP)

In the FUSION trial the interaction between SP Energy Networks (DSO) and the aggregators has been formalised through the USEF Flexibility Trading Protocol (UFTP). The scope of this learning objective was to analyse the experience of aggregators and DSO while using the protocol; potential improvements; and to capture the contributions from Project FUSION to the protocol. In summary, the findings during this phase are:

- Aggregators and SP Energy Networks found the experience with UFTP smooth and positive. Aggregators perceive that the complexity of the protocol is on par with other protocols that cover similar processes.
- Improvements regarding settlement and congestion point hierarchy were identified by DSO, aggregators and FFP provider.
- FUSION Project is interacting with SHAPESHIFTER TSC to discuss potential improvements to the UFTP protocol and is in the process of submitting a change request regarding congestion point hierarchy.
- Previous change requests and feedback given by Project FUSION has already been implemented in version 3 of the protocol.

Refer to section 4.6 of this report for full analysis of this objective.

DSO procurement mechanism cost drivers

The trial results suggest that the different cost drivers considered would have a significant impact on the volume of flexibility required by the DSO to ensure that the required flexibility is delivered. In particular the baseline accuracy has a large impact, for the FUSION trial as well as BaU, and therefore is an area that requires attention as the trial moves into the next stages.

An even split in the risk of reliability of delivery (and baselining implications) between the DSO and aggregators was assumed, however it is important to have a better understanding on how to split the risks between DSO and aggregator. Besides, it is key to understand how different measures would impact both the DSO and aggregators, for example if a certain level of baseline accuracy was required, some flexible technologies might be excluded, leaving more expensive technologies which would come at a higher cost for the DSO. The following questions will be explored in the next stages of the trial:

- How does the risk distribution affect the flexibility cost?
- How can it be achieved without hampering the entry of flexibility into the market?
- How does it affect the decision process of the DSO?
- Should reliability and baseline quality be included in the tendering process? How would that affect the aggregator and the DSO?
- How would the inclusion of other baseline methodologies, e.g. historical with same-day-adjustment, would affect the DSO?

The comparison between the trial results and a hypothetical business-as-usual case has indicated that the FUSION trial requires less additional flexibility at four of the seven congestion points. This shows that the USEF framework can reduce uncertainty in the drivers that affect flexibility procurement costs and therefore reduce DSO costs compared with BaU flexibility markets.

Refer to section 4.7 of this report for full analysis of this objective.

Commercial Mechanisms

One of the aims of Project FUSION is to explore the commercial mechanisms that USEF offers to encourage consumer participation. The key conclusions related to this objective to date, based on reflections on the trial and feedback from participating aggregators, are as follows:

- One aggregator has found challenges in bringing-on additional flexible assets in Phase 2 of the trial to meet their contracted availability volume. They noted that the technical challenges associated with enabling new assets and dealing with businesses with multiple subcontractors has increased the lead time of new connections.
- It was also noted that the requirement to state the available capacity six month ahead of delivery is making it more challenging to bring on new customers due to uncertainty in revenue, penalties, sub-optimised flexibility use. Short term markets would allow aggregators to be more certain about the availability of flexibility, and would make it easier to onboard new assets that are considered non-firm capacity into the market, which in turn would enable more efficient use of flexibility and more revenue to their customers. (Note that this section does not refer to contract duration between aggregator and customer but rather between DSO and aggregator.)
- Aggregators continue to recommend that the balance between utilisation and availability incentives could be improved by rewarding delivery over availability.
- Notification time between FlexOrder and delivery is important to customers. Ordering day ahead provides customer with more visibility of when their assets will be utilised and is therefore more appealing to them.

- While it is recognised that USEF's free bids mechanism provides more opportunity for revenue through enabling additional income outside of long-term contracts. FUSION's free bid system is not mature enough yet to fully leverage this mechanism therefore its ability to attract new customers is not clear at this stage but will continue to be studied as the trial develops.

Refer to section 4.8 of this report for full analysis of this objective.

NEXT STEPS [5]

The FUSION trial will run until end of March 2023. Once finalised, all data will be captured and to provide an updated analysis of the various learning objectives listed above. Next to that, Project FUSION will address the remaining objectives, titled:

- Cost Benefit Analysis (CBA)
- Demand side flexibility (DSF) potential;
- Business case of USEF-based flexibility;
- Efficient DNO network management; and
- Coordination with the ESO

The cost benefit analysis objective is currently being finalised and a separate report is expected in February 2023.

The objective on "coordination with the ESO" will be based on an ongoing trial between SP Energy Networks and the ESO and will conclude with a report of findings due February 2023.

Finally, the dissemination of the learnings of the project will conclude with a closing report in November 2023, when the end date of Project FUSION is set.

[5] Please refer to Section 6 for further details

1. Introduction

1.1. OVERVIEW OF PROJECT FUSION

Project FUSION is funded under Ofgem's 2017 Network Innovation Competition (NIC), to be delivered by SP Energy Networks in partnership with the following project partners: DNV (formerly: DNV GL), Origami Energy recently acquired by Baringa, Imperial College London (academic partner), SAC Consulting, The University of St. Andrews, and Fife Council.

Project FUSION represents a key element of SP Energy Network's transition to becoming a Distribution System Operator, taking a step towards a clean, smart and efficient energy system. As the electricity system changes from a centralised to decentralised model, it enables the functioning of a smarter and more flexible network. Project FUSION is trialling the use of commoditised local demand-side flexibility through a structured and competitive market, based on a universal, standardised market-based framework; the Universal Smart Energy Framework (USEF). USEF provides a standardised framework that defines products, market roles, processes and agreements, as well as specifying data exchange, interfaces and control features. The purpose of USEF is to accelerate the transition to a smart, flexible energy system to maximise benefits for current and future customers.

FUSION will also inform wider policy developments around flexibility markets and the DNO-DSO transition through the development and testing of standardised industry specifications, processes, and requirements for transparent information exchange between market participants accessing market-based flexibility services. Ultimately, FUSION will contribute to Distribution Network Operators and all market actors unlocking potential and value of local network flexibility in a competitive and transparent manner. In doing so, FUSION aims to contribute to addressing the energy trilemma by making the energy system more secure, affordable and sustainable.

1.2. USEF OVERVIEW

The USEF framework aims to facilitate effective coordination across all the different actors involved in the electricity market by providing a common standardised roles model and market design while describing communication requirements and interactions between market roles. USEF turns flexible energy use into a tradeable commodity available for all energy market participants, separated from (but in coordination with) the traditional electricity supply chain, to optimise the use of resources. USEF focuses on explicit demand-side flexibility, in which prosumers are contracted by the aggregator to provide specific flexibility services using Active Demand and Supply (ADS) assets. USEF acknowledges but does not provide detailed considerations for implicit demand-side flexibility or peer-to-peer energy trading.

To facilitate the transition towards a cost-effective and scalable model, the framework provides the essential tools and mechanisms which redefine existing energy market roles, add new roles and specify interactions and communications between them. In addition, the USEF standard ensures that all technologies and projects will be compatible and connectable to the energy system, facilitating project interconnection, hence fostering innovation and accelerating the smart energy transition. By delivering a common standard to build on, USEF connects people, technologies, projects and energy markets in a cost-effective manner. Its market-based mechanism defines the rules required to optimise the whole system, ensuring that energy is produced, delivered and managed at lowest cost for the whole system and effectively for the end-user. The USEF framework provides:

- a standardised common framework designed to be implemented on top of current energy markets such as wholesale, retail and capacity markets.

- A description of the flexibility value chain (FVC) involving new and existing market players and giving a central role to the aggregator in facilitating flexibility transactions.
- A roles model and interaction model to enable the implementation of different business models and interactions between actors
- A market design described by the Market Coordination Mechanism (MCM) which sets out the phases and interaction requirements for flexibility transactions. The MCM provides all stakeholders with equal access to a smart energy system. To this end, it facilitates the delivery of value propositions (i.e. marketable services) to various market parties without imposing limitations on the diversity and customisation of those propositions.
- Detailed communication and markets access requirements taking into considerations privacy and cybersecurity issues.

The USEF framework was initially developed by the USEF Foundation. In 2014, the USEF Foundation was inaugurated to accelerate the establishment of an integrated smart energy market which benefited all stakeholders, from energy companies to consumers. USEF was an early mover, a combined force of parties and professionals with a shared goal. Together they explored new territories to help unlock and structure the future market and, as a result, many elements of USEF can now be found in standardisation and harmonisation policies at both national and European level.

In 2021, 7 years later, the work of the USEF Foundation was therefore considered complete and USEF Foundation had ceased to exist by 1 July. To safeguard the legacy of the USEF foundation, the USEF framework, including the UFTP protocol (recently rebranded to Shapeshifter) is being maintained by the GOPACS organisation. The SHAPESHIFTER protocol has also been adopted by the Linux Energy Foundation, offering a platform for the maintenance and support of the protocol.

1.3. BACKGROUND TO THIS DOCUMENT

Project FUSION commenced in September 2018. Since then, a number of significant milestones and preparatory activities have been completed, culminating in the commencement, in September 2021, of the live FUSION trials, which marked the first deployment in GB of a USEF-compliant flexibility market.

1.4. PURPOSE OF THIS DOCUMENT

Project FUSION has prepared this document to report upon the progress, implementation and interim learnings from Phase 2 of the FUSION trial which commenced in April 2022, as well as to outline the planned next steps for the project.

This document provides an overview of:

5. The background of the trial design and its operation to date, including an overview of flexibility providers and flexibility assets that have been participating in the trial, the detailed service requirements and the trial cases that have been simulated.
6. The analysis of the trial operation to date, key statistics on delivered flexibility, prices, flexibility offers and orders;
7. Assessment of delivery against agreed objectives for the FUSION trial phase 2;
8. Learnings from stakeholders and participants in the FUSION trial phase 2;
9. FUSION's current progress with stakeholder engagement and
10. Next steps, which are planned to commence in November 2022.

2. Trial design & operation – Phase 2

FUSION's phase 2 trial started in April 2022. In comparison to phase 1, the design of the second phase of the FUSION trial was adapted to test the effectiveness of real time forecasts from the DSO, instead of the simulated forecasts that were used in phase 1.

This section describes the main characteristics of the trial design and operation. Section 2.1 describes the roles and the parties responsible for those roles in the FUSION trial. Then, Section 2.2 describes the flexibility characteristics, namely the services that can be provided, their location, the detailed service requirements as set in the Fusion Service Requirement documentation (FSR), and the description of the flexible assets. Finally, Section 2.3 describes the three flexibility use cases, and the relevant test cases for each, adapted to incorporate the real time element of the phase 2 trials.

2.1. TRIAL ROLES AND RESPONSIBILITIES

FUSION partners agreed on the FUSION USEF Implementation Plan, covering the flexibility services and the USEF roles that the trial seeks to test. Table 1 sets out the roles included in the trial and the market parties responsible for performing them.

Table 1 USEF roles in the FUSION trial

USEF Role	Inclusion in FUSION trial	Performed by	Comments
Distribution System Operator (DSO)	Yes	SP ENERGY NETWORKS	
Electricity System Operator (ESO)	No	n/a	
Prosumer	Yes	DERs owners contracted by participating aggregators	
Active Demand Supply (ADS)	Yes	DERs managed by participating aggregators	
Aggregator	Yes	Flexibility providers: Engie and Orange Power	Selected Through industry engagement and tendering process
Supplier	No	n/a	

Capacity Service Provider (CSP)	No	n/a	The aggregator can also be active in the capacity market, but the trial will not test the interactions with this role
Constraint Management Service Provider (CMSP)	Yes	Flexibility providers: Engie and Orange Power	Through industry engagement and tendering process
Balancing Services Provider (BSP)	No	n/a	The aggregator can also be active in balancing products, but trial did not test interactions with this role yet
Balance Responsible Party (BRP)	No	n/a	The aggregator can also be active in wholesale trading, but the trial did not test interactions with this role
Common Reference Operators (CRO)	Yes	SP ENERGY NETWORKS	
Meter Data Company (MDC)	Yes	SP ENERGY NETWORKS	SP ENERGY NETWORKS will take this role by default
Allocation Responsible Party (ARP)	No	n/a	Wholesale settlement is out of scope

2.2. FLEXIBILITY CHARACTERISTICS

This section provides a high-level description of the available DSO flexibility services, their locations and requirements for each of the DSO congestion management zones.

2.2.1 DSO Flexibility Services

Three DSO Services were procured in the two selected primary substation and three feeder locations for trial phase 2:

- Sustain Peak Management: A service to provide the DSO with a planned reduction in demand or increase in generation in advance of a forecast capacity constraint at peak time, e.g. reducing the loading on a transformer during tea-time peak.
- Secure DSO Constraint Management (pre-fault): A service to provide the DSO with an immediate reduction in demand or increase in generation during a planned outage of one or more critical assets on in the event of network disturbances to maintain security standards and avoid any customer minutes lost.

- Dynamic DSO Constraint Management (post-fault): A service to provide the DSO with an immediate reduction in demand or increase in generation following an unplanned outage of one or more critical assets to maintain security standards and avoid any customer minutes lost.

2.2.2 Location of Flexibility

The project trial area of East Fife is defined as the network area supplied by the primary substations at St Andrews and Leuchars. This area was selected because both recent load growth and the integration of distributed generation can lead to localised network constraints which FUSION could alleviate.

In phase 1 of the FUSION trial, all flexible units including distributed energy resources (DERs) and flexible assets, had to be located within the area that is normally supplied by Leuchars primary substation and St. Andrews primary substation. In phase 2, DER and flexible assets participating in the trial could also be in areas normally supplied by St. Andrews 11 KV Feeders 18612, 18614 and 18616. A map showing the FUSION trial location can be found in Figure 1.

More information on the postcodes served by the St. Andrews and Leuchars can be found in the FUSION Flexibility Services Requisition (FSR) for each location. [6 7 8 9 10]

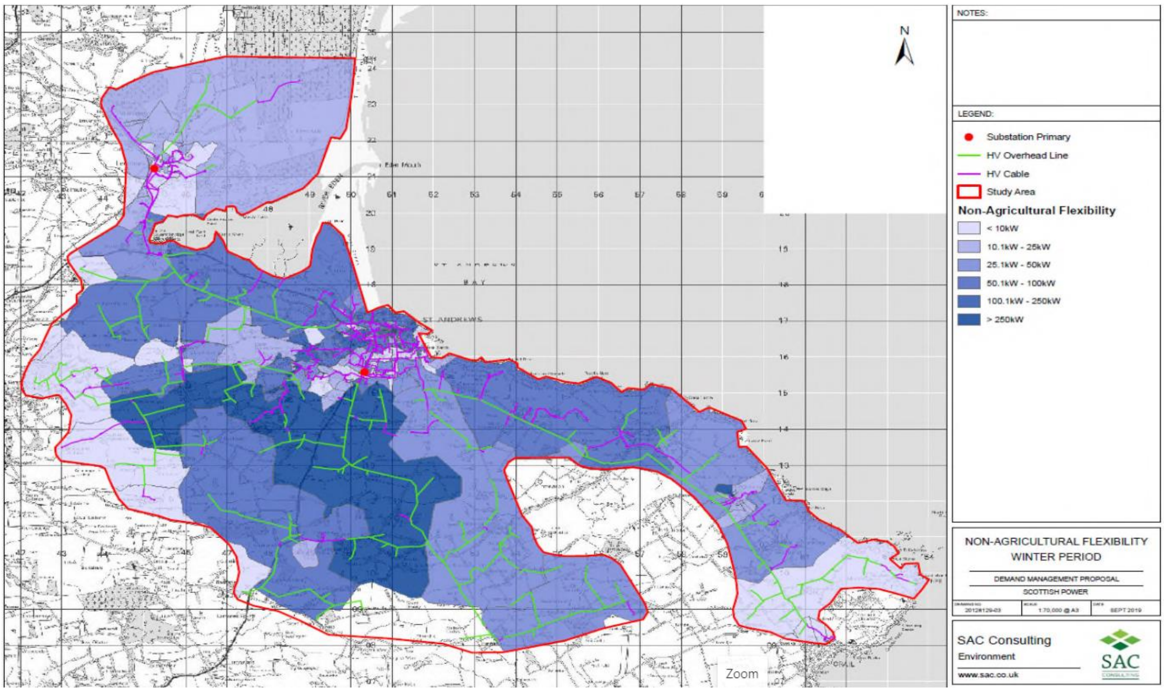

Figure 1 FUSION project trial location.

2.2.3 Detailed service requirements

There were two events for which the trial anticipated having to provide standby capacity:

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[6] FSR Leuchars: FUSION_Flexibility_Services_Requisition_Leuchars_SP ENERGY NETWORKS.pdf (SP Energy Networksergynetworks.co.uk)

[7] FSR St. Andrews: FUSION_Flexibility_Services_Requisition_St_Andrews_SP ENERGY NETWORKS.pdf (SP Energy Networksergynetworks.co.uk)

8 FSR St. Andrews 11 KV Feeder 18612: FUSION Service Request (FSR) - St-Andrews 11 kV _SP ENERGY NETWORKS.pdf

[9] FSR St. Andrews 11 KV Feeder 18614: FUSION Service Request (FSR) – St-Andrews 11 kV _SP ENERGY NETWORKS.pdf

[10] FSR St. Andrews 11 KV Feeder 18616: FUSION Service Request (FSR) – St-Andrews 11 kV _SP ENERGY NETWORKS.pdf

- To de-risk the N-1 event from planned maintenance scheduled at the St Andrews Primary.
- To accommodate the peak loads on the Primary Substation associated with the St. Andrews open

Nonetheless, as there was no urgent or imminent need for flexibility in the study area during the phase 2 trial period, the FSR was not designed to meet any specific network needs, it was designed to maximise the value and learnings from the trial.

The key factors when determining the quantity of the flexibility availability to be procured through the FSR tender were the following:

- Minimizing the possibility of erroneously creating undesired risk to the network from flexibility dispatches from the trial (keep then below 500kW)
- Maximizing the amount of data that can be generated to ensure that it is of sufficient volume to allow for statistically robust analysis.
    - Maximize number of dispatches
    - Maximize variety of CP voltages
    - Maximize diversity of flexibility services tested
- Provide maximum impact and bandwidth for trial delivery
    - Ensure availability is within office hours
    - Secure availability throughout trail period

The flexibility requirements for each location have been published in the Fusion Service Request (FSR) documents and are summarised in the tables below for the two primaries and three feeders.

Table 2 Flexibility requirements in St. Andrews

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-250	250	Apr22-Sept22	Mon – Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-250	250	Oct22-Mar23	Mon – Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-250	250	Apr22-Sept22	Mon – Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-250	250	Oct22-Mar23	Mon – Fri	11:30 – 14:30	Secure DSO Constrai	60

							nt Management (Pre-fault)	
5	2022/23	-250	250	Apr22-Mar23	Mon – Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 3 Flexibility requirements in Leuchars

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-250	250	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-250	250	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-250	250	Apr22 – Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constrai	60

							nt Management (Post-fault)	

*a positive value represents an increase in demand or export; negative is the opposite

Table 4 Flexibility requirements in St. Andrews 11kV Feeder 18612

		Response Type*						
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-150	150	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-150	150	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-150	150	Apr22-Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 5 Flexibility requirements in St. Andrews 11kV Feeder 18614

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak Management	60
2	2022/23	-500	500	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-250	250	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-500	500	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-250	250	Apr22 – Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Table 6 Flexibility requirements in St. Andrews 11kV Feeder 18616

Response Type*								
Ref	Year	Demand (kW)	Generation (kW)	Period	Days	Service Window	Service Type	Max run time (mins)
1	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:00 – 14:00	Sustain Peak	60

							Management	
2	2022/23	-150	150	Oct22-Mar23	Mon - Fri	10:30 – 15:30	Sustain Peak Management	60
3	2022/23	-100	100	Apr22-Sept22	Mon - Fri	11:30 – 13:30	Secure DSO Constraint Management (Pre-fault)	60
4	2022/23	-150	150	Oct22-Mar23	Mon - Fri	11:30 – 14:30	Secure DSO Constraint Management (Pre-fault)	60
5	2022/23	-100	100	Apr22-Mar23	Mon - Fri	12:30 – 14:30	Dynamic DSO Constraint Management (Post-fault)	60

*a positive value represents an increase in demand or export; negative is the opposite

Project FUSION has developed additional service requirements which have been specified within the Flexibility Service Agreements (FSAs) between the aggregators and SP Energy Networks.[11] These additional service requirements are described below:

1. Maximum Response Time: This parameter depends on the service. Sustain Peak Management, Secure DSO Constraint Management (pre-fault) and Dynamic DSO Constraint Management (post-fault) have a maximum response time of 17 hours, 30 minutes and 15 minutes respectively.
2. Minimum Sustain Time: 60 minutes
3. Metering requirements: Minute-by-minute metering is required to monitor the provision of the flexibility services aggregated in 30-minute intervals for data sharing purposes.

[11] Flexibility Service Agreement (FSA) template: Flexibility_Services_Agreement_Template.pdf (SP Energy Networksergynetworks.co.uk)

4. Metering point: The metering point can be at asset level (i.e. sub-metering) or at boundary level (i.e. the main meter between the Site on which the Distributed Energy Resource (DER) is located and the SP Energy Networks network).
5. Baseline for measuring delivery: A nomination baseline is used for the settlement of the delivered flexibility. As per USEF terminology, the D-programme which is issued before the Flexibility Offer is used as baseline.

2.2.4 Flexible asset breakdown and flexibility providers

The trial has attracted and enabled aggregators to offer flexibility from end consumers within a variety of sectors and asset types. Figure 2 below shows that most of the flexibility (34%) is provided by EV chargers. In total, the contracted flexibility is about 1.5 MW.

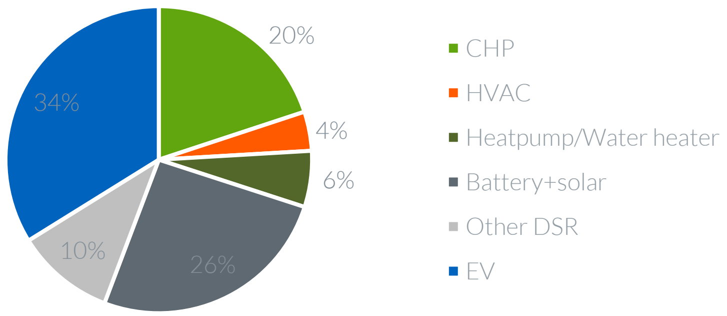


Figure 2 Flexible asset breakdown in the FUSION trial.

The following tables, Table 7Error! Reference source not found. and Table 8Error! Reference source not found., provide an overview of Gridimp and Orange Power aggregators' assets respectively at the five congestion points, the two primaries and the three feeders, and their flexible capacity. Orange Power uses all residential assents and Gridimp commercial and industrial; resulting in 80% of the assets used for the trial being residential assets.

Table 7 Gridimp overview of assets at each congestion point

Aggregator name	Congestion point	Type	Flexible Capacity [kW]
Gridimp	Leuchars Primary	CHP	60
Gridimp	St Andrews Primary	HVAC	40
Gridimp	St Andrews Primary	CHP	220
Gridimp	St Andrews Primary	HVAC	8
Gridimp	St Andrews Primary	HVAC	10

Table 8 Orange Power overview of assets at each congestion point

Aggregator name	Congestion point	Type	Flexible Capacity [kW]
Orange Power	Leuchars Primary	EV	210
Orange Power	Leuchars Primary	Heat pump/ water heater	25
Orange Power	Leuchars Primary	Battery + solar	115
Orange Power	Leuchars Primary	Other DSR	58
Orange Power	St Andrews Primary	EV	340
Orange Power	St Andrews Primary	Heat pump/ water heater	40
Orange Power	St Andrews Primary	Battery + solar	211
Orange Power	St Andrews Primary	Other DSR	69
Orange Power	St Andrews 11kV-18612	EV	41
Orange Power	St Andrews 11kV-18612	Heat pump/ water heater	6
Orange Power	St Andrews 11kV-18612	Battery + solar	12
Orange Power	St Andrews 11kV-18612	Other DSR	7
Orange Power	St Andrews 11kV-18614	EV	45
Orange Power	St Andrews 11kV-18614	Heat pump/ water heater	6
Orange Power	St Andrews 11kV-18614	Battery + solar	12
Orange Power	St Andrews 11kV-18614	Other DSR	6
Orange Power	St Andrews 11kV-18616	EV	49

Orange Power	St Andrews 11kV-18616	Heat pump/ water heater	6
Orange Power	St Andrews 11kV-18616	Battery + solar	12
Orange Power	St Andrews 11kV-18616	Other DSR	6

The tables above show the actual flexibility that was enabled and activated throughout the trial. This differs to what was registered in the Flexibility Service Agreements (FSA), one aggregator being able to attract significantly more flexible capacity than what is included in the agreement, and the other less. For the latter, there were some CHP and HVAC assets that were unexpectedly unable to provide flexibility due to an incident with the university's district heating system which, in-turn, affected their usage regimes.

2.3. OPERATION – MAIN DIFFERECES BETWEEN PHASE 1 AND 2

This section presents the overview of the test cases simulated during the trial phase 2. The main difference between phase 1 and 2 is that for phase 2, real time forecasts from the DSO were used instead of the simulated forecasts used for phase 1. As such, the test cases needed to be adapted incorporating the steps for the DSO to take into account the real-time developments.

Although there was no real congestion affecting the substations and feeders, the cases were designed so that flexibility would be dispatched by simulating a number of plausible events. Within each use case there are several test cases depending on the day-ahead and intraday forecast of the substation or feeder load.

The first subsection below describes the use cases that were adapted to include the real-time element of phase 2 of the trial. These use cases explain the logic that the DSO follows to trade flexibility, i.e., to request flexibility from the aggregators and then order it when required (i.e., issue a FlexOrder). Then, the second subsection shows statistics on the number of events simulated per test case and per range of requested power.

It is worth noting that the simulations were executed according to a schedule that was designed to ensure that all test cases were trialled and that a high turn-over of events were achieved to maximise the volume of relevant empirical data generated for subsequent analysis within the boundaries of the contracts.

2.3.1 Overview of use cases and test cases deployed in Phase 2

2.3.1.1 Use case – Secure DSO Constraint Management (pre-fault)

Use case description: There is a need to reduce the demand on a distribution network asset [immediately or at least within the hour] under certain system conditions and at certain times of day for a maximum duration of time to keep that asset within its operational capability. This could support the network to avoid fault conditions, during both planned and un-planned maintenance work, or where a constraint is forecast, using a DSO-triggered service.

The flexibility required can come from one of three actions that help to reduce demand at the Meter Point Administration Number (MPAN): (1) a reduction in demand, (2) an increase in generation, or (3) discharging a battery.

Test case 1.1 - Secure DSO Constraint Management (pre-fault) - Reserve + Order/ No Order

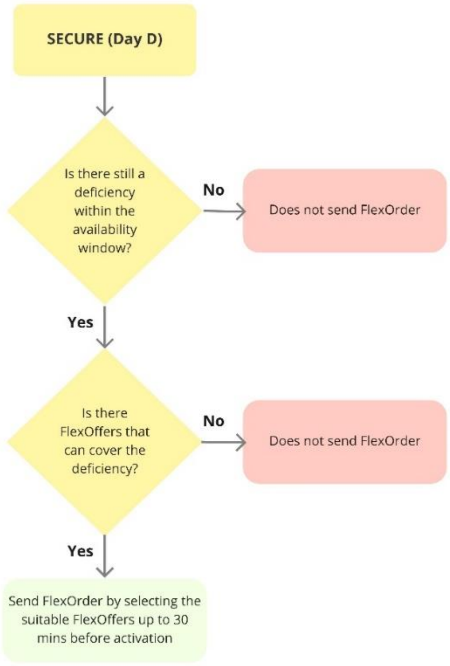
To reserve and issue an order for flexibility under the Secure DSO Constraint Management product, the DSO would observe the following preconditions during day-ahead (D-1) and intraday (D) operation:

- Day D-1: The grid forecasted profile for day D is received by the operator. The operator sets the power threshold according to the power threshold document and the deficiency power range given in the test case schedule to simulate congestion. The FFP shows a deficiency within the availability windows[12]. This triggers the operator to send FlexRequests for day D.
- Day D: The operator receives the forecast for day D and takes the following steps, illustrated in Figure 3.
    - Firstly, the operator visually checks whether there is a deficiency.
        - If there is not, the operator does not send FlexOrders.
        - If there is, the operator checks if there are FlexOffers that can cover the deficiency. Note that the DSO can opt for partial activation of the flex offer(s).
            - If there are, the operator sends the FlexOrders up to 30 minutes before the needed activation based on bid price and volume.
            - If not, the operator does not send FlexOrders.

Then, the operator fills in two fields in the schedule excel, indicating whether the FlexOrders were sent or not, and the observations/reasoning behind the decision, for instance, if the deficiency calculated based on D-1 forecast is above, below, or equal to the deficiency shown in the D forecast.

Figure 3 Flow chat illustrating the step-by-step approach for day D for the test case 1.1, SECURE.

[12] Availability windows can be found in the tables in Section 2.2.3.



Test case 1.2 - Secure DSO Constraint Management (pre-fault) – Free Bid + Order / No Order

To reserve flexibility under the Secure DSO Constraint Management product, the DSO would observe the following preconditions:

- Day D-1: The grid forecasted profile for day D is received by the operator. The operator sets the power threshold according to the power threshold document and the deficiency power range given in the test case schedule to simulate congestion. If shows a deficiency outside the availability windows[12]. This triggers the operator to send FlexRequest for day D.

- Day D: The operator receives the forecast for day D and takes the following steps.
    - Firstly, the operator visually checks whether there is a deficiency:
        - If there is not, the operator does not send FlexOrders.
        - If there is, the operator checks if there are free bid FlexOffers that can cover the deficiency. Note that the DSO can opt for partial activation of the flex offer(s).
            - If there are, the operator sends the FlexOrders up to 30 minutes before the needed activation based on bid price and volume.
            - If not, the operator does not send FlexOrders.

The flow chart and visualisation are the same as case 1.1, Figure 3, except the deficiency would occur outside the availability window, unless during weekends.

Test case 1.3 - Secure DSO Constraint Management (pre-fault) - FlexReservationUpdate

- Day D-1: The grid forecasted profile for day D is received by the operator. The operator sets the power threshold according to the power threshold document. The FFP does not show a deficiency either within or outside the availability windows. This triggers the operator to send a FlexReservationUpdate.

2.3.1.2 Use case – Dynamic DSO Constraint Management (post-fault)

Use case description: There is a need to reduce the demand on a distribution network asset immediately following a network fault, for a maximum duration to keep that asset within its operational capability. This service is unplanned but could be scheduled at times of high network risk.

The flexibility required can come from one of three actions that help to reduce demand at the substation: (1) a reduction in demand, (2) an increase in generation, or (3) discharging a battery.

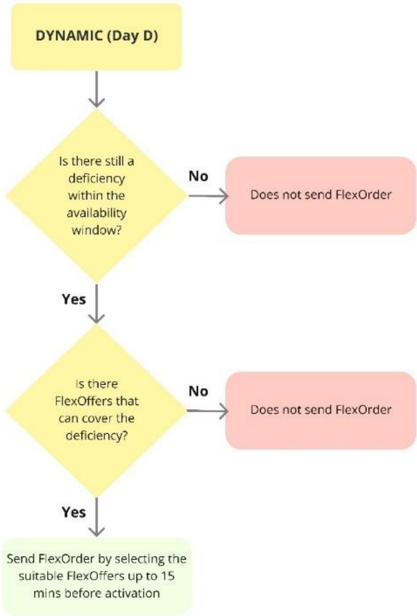
Test case 2.1 – Dynamic DSO Constraint Management (post-fault) - Reserve + Order / No Order

To reserve and order flexibility under the Dynamic DSO Constraint Management product, the DSO would observe the following preconditions:

- Day D-1: The grid forecasted profile is received by the operator for day D. The operator sets the power threshold simulating a potential fault according to the power threshold document and the deficiency power and time given in the test case schedule. It shows a deficiency within the availability window[12]. This triggers the operator to send FlexRequests for the following day.
- Day D: The operator receives the forecast for day D and takes the following steps, illustrated in Figure 4.
    - A fault occurs; thus the threshold is kept as it was the day before, i.e. with a momentaneous decrease of the maximum power threshold. The operator evaluates whether there is a deficiency:
        - If there is not, the operator does not send FlexOrders.
        - If there is, the operator checks if there are FlexOffers that can cover the deficiency. Note that the DSO can opt for partial activation of the flex offer(s).
            - If there are, the operator sends the FlexOrders up to 15 minutes before the needed activation based on bid price and volume.
            - If not, the operator does not send FlexOrders.

Then, the operator fills in two fields in the schedule excel, indicating whether the FlexOrders were sent or not, and the observations/reasoning behind the decision, for instance, if the deficiency calculated based on D-1 forecast is above, below, or equal to the deficiency shown in the D forecast.

Figure 4 Flow chat illustrating the step-by-step approach for day D for the test case 2.1, DYNAMIC.



Test case 2.2 - Dynamic DSO Constraint Management (post-fault) - Reserve + no Order

To reserve flexibility under the Dynamic DSO Constraint Management product and to not order it during intraday, there are certain preconditions that the DSO would observe during day-ahead (D-1) and intraday (D) operation:

- Day D-1: The grid forecasted profile is received by the operator for day D. The operator sets the power threshold simulating a potential fault according to the power threshold document and the deficiency power and time given in the test case schedule. It shows a deficiency within the availability window[12]. This triggers the operator to send FlexRequests for the following day.
- Day D: The operator receives the forecast for day D and takes the following steps, illustrated in Figure 4.
    - Fault does not occur; thus, the threshold is changed to a straight line (without the well). The operator does not send flex orders.

Test case 2.3 - Dynamic DSO Constraint Management (post-fault) - Free bid + Order / No Order

To request free bids and activate them under the Dynamic DSO Constraint Management product, there are certain preconditions that the DSO would observe during day-ahead (D-1) and intraday (D) operation:

- Day D-1: The grid forecasted profile is received by the operator for day D. The operator sets the power threshold simulating a potential fault according to the power threshold document and the deficiency power and time given in the test case schedule. It shows a deficiency outside the availability windows[12]. This triggers the operator to send FlexRequests for the following day.
- Day D: The operator receives the forecast for day D and takes the following steps, illustrated in Figure 3.
    - A fault occurs; thus, the threshold is kept as it was the day before, i.e. with well-shape. The operator evaluates whether there is a deficiency:
        - If there is not, the operator does not send FlexOrders.

    - If there is, the operator checks if there are FlexOffers that can cover the deficiency. Note that the DSO can opt for partial activation of the flex offer(s).
        - If there are, the operator sends the FlexOrders up to 15 minutes before the needed activation.
        - If not, the operator does not send FlexOrders.

Then, the operator fills in two fields in the schedule excel, indicating whether the FlexOrders were sent or not, and the observations/reasoning behind the decision, for instance, if the deficiency calculated based on D-1 forecast is above, below, or equal to the deficiency shown in the D forecast.

The flow chart and visualisation are the same as case 2.1 except the deficiency would occur outside the availability window, unless during weekends.

Test case 2.4 – No fault outside availability window - Free bid + no Order

To request free bids and not activate them under the Dynamic DSO Constraint Management product, there are certain preconditions that the DSO would observe during day-ahead (D-1) and intraday (D) operation:

- Day D-1: The grid forecasted profile is received by the operator for day D. The operator sets the power threshold simulating a potential fault according to the power threshold document and the deficiency power and time given in the test case schedule. It shows a deficiency outside the availability window[12]. This triggers the operator to send FlexRequests for the following day.
- Day D: The operator receives the forecast for day D and takes the following steps, illustrated in Figure 3.
    - Fault does not occur; thus, the threshold is changed to a straight line (without the well). The operator does not send flex orders.

Test case 2.5 - Dynamic DSO Constraint Management (post-fault) - FlexReservationUpdate

To send the aggregators a FlexReservationUpdate to release them from their availability obligation at a certain day, under the Dynamic DSO Constraint Management product, there are certain preconditions that the DSO would observe during day-ahead (D-1).

- Day D-1: The grid forecasted profile for day D is received by the operator. The operator sets the power threshold according to the power threshold document. The FFP does not show a deficiency either within or outside the availability windows[12]. This triggers the operator to send a FlexReservationUpdate to release the flexibility contracted for the following day.

2.3.1.3 Use case – Sustain Peak Management

Use case description: There is a need to reduce the demand on a distribution network asset to keep that asset within its normal operational capability. This could be as a result of a forecast capacity constraint on the asset at a particular time, e.g. to reduce the demand on a critical asset during winter tea-time peak, using a DSO planned service. This service supports the deferral or avoidance of conventional approaches to network reinforcement.

The flexibility required can come from one of three actions that help to reduce demand at the MPAN: (1) a reduction in demand, (2) an increase in generation, or (3) discharging a battery.

Test case 3.1 – Sustain Peak Management - Reserve + Order

To reserve and order flexibility under the Sustain Peak Management product, there are certain preconditions that the DSO would observe during day-ahead (D-1):

- Day D-1: The grid forecasted for day D profile is received by the operator. The operator sets the power threshold according to the power threshold document and the deficiency power range given in the test case schedule to simulate congestion. It shows a deficiency within the availability windows[12].
    - This triggers the operator to send FlexRequest for day D.
    - The operator receives and selects suitable FlexOffers to cover the deficiency.
    - The operator sends FlexOrder.

This procedure is illustrated with the flowchart in Figure 5.

Figure 5 Flow chat illustrating the approach for day D-1 for the test case 3.1, SUSTAIN

Test case 3.2 - Sustain Peak Management - Free bid + Order (when possible)

To request free bids and activate them under the Sustain Peak Management product, there are certain preconditions that the DSO would observe during day-ahead (D-1) operation:

- Day D-1: The grid forecasted for day D profile is received by the operator. The operator sets the power threshold according to the power threshold document and the deficiency power range given in the test case schedule to simulate congestion. It shows a deficiency within the availability windows[12].
    - This triggers the operator to send FlexRequest for day D.
    - The operator receives and selects suitable free bid FlexOffers to cover the deficiency.
    - The operator sends FlexOrder.

The flow chart and visualisation are the same as case 3.1 except the deficiency would occur outside the availability window, unless during weekends.

- Test case 3.3 - Sustain Peak Management - FlexReservationUpdate

To send the aggregators a FlexReservationUpdate to release them from their availability obligation at a certain day, under Sustain Peak Management product, there are certain preconditions that the DSO would observe during day-ahead (D-1).

- Day D-1: The grid forecasted profile for day D is received by the operator. The operator sets the power threshold according to the power threshold document. The FFP does not show a deficiency either within or outside the availability windows[12]. This triggers the operator to send a FlexReservationUpdate to release the flexibility contracted for the following day.

2.3.2 Summary of test cases deployed in Phase 2

Phase 2 of the FUSION project trialled the different test cases for the two primary substation at St. Andrews and Leuchars, as well as the St. Andrews 11 KV Feeders 18612, 18614 and 18616, all in the East Fife area.

Each simulation tested how FUSION trial participants (FTPs) responded to the different test cases outlined above. The number of simulations of each test case at each congestion point is shown below in Figure 6. The simulation schedule focused on test cases where flexibility is ordered (i.e. test cases

1.1, 2.1 and 3.1) to maximise the volume of empirical data generated where flexibility is delivered. The schedule also ensured that there was data on all the other test cases.

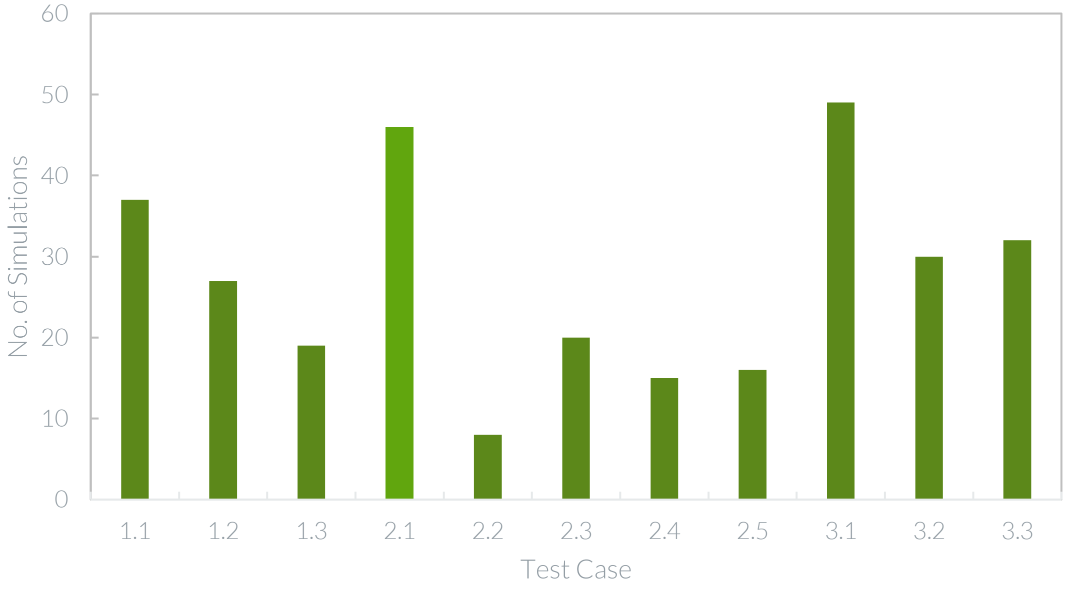


Figure 6 Number of simulations for each test case at all congestion points

The distribution of power requested is shown in Figure 7. Phase 2, compared to phase 1, has tested the 0-50 kW range more due to the lower quantity of capacity available at feeder level. At substation level in St Andrews and Leuchars, where there is more flexibility connected available, FUSION was able to test requesting greater amounts of flexibility.

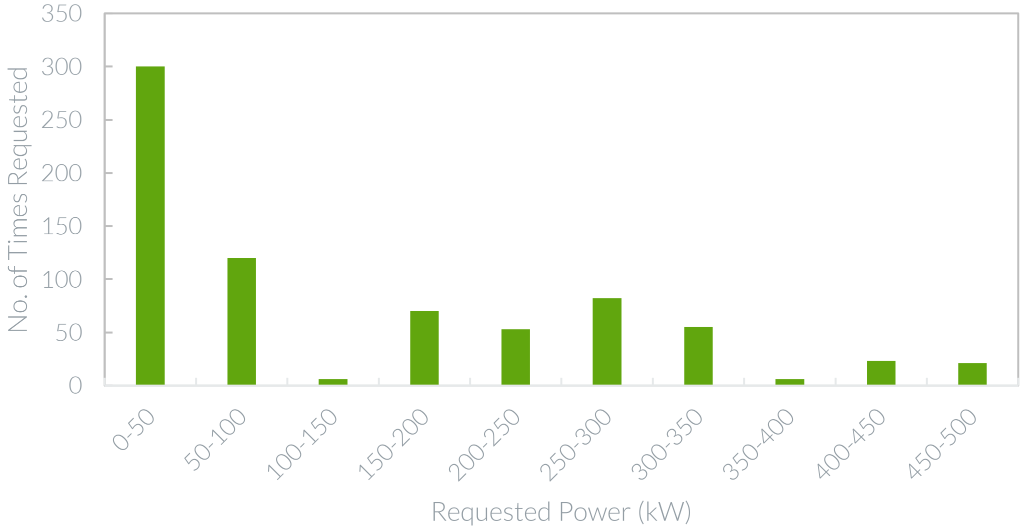


Figure 7 Histogram showing the range of power requested across all congestion points

3. Trial simulation overview

This section provides an overview of the results from Phase 2 of the trial and offers insights into the delivered flexibility and the observed trends in requests, offers and orders. The section outlines the method used to analyse the available data before looking at three key topic areas: trial summary statistics, reliability of delivery and offer prices. For each topic, we provide the scope of the analysis, the results and the interim learnings and conclusions.

3.1. GENERAL REMARKS

The primary analysis for Phase 2 has been conducted on data collected between 18/04/2022 and 01/10/2022, which corresponds to the start of Phase 2 trial period and a deadline that the project had to impose to be able to complete the analysis in time for the report to be published in November 2022. The data included the following:

1. Meter data - from each aggregator at portfolio level at each congestion point and from the DSO at the substation.
2. Validation Phase Information – including D-programmes, FlexRequests, FlexOffers and FlexOrders.
3. Trial Simulation Schedule – a pre-determined list of the FlexRequests and FlexOrders to be placed. The trial simulation schedule includes the plan for activating the test cases examined in this trial. This schedule acted as a guideline for the DSO however individual decisions of whether to order flexibility were made on a day-to-day basis.
4. Settlement Information – showing payments due for delivered flexibility for each event and each aggregator.

The data was downloaded from the FUSION Flexibility Platform's (FFP) central database using a combination of Structured Query Language (SQL) scripts and power query. It was then cleansed to avoid duplicate database entries and post-processed to enable the analysis to be done.

Meter data from aggregators was typically only available for those days that FlexRequests were issued. The meter data includes the half-hourly imported and exported energy, which was then converted into net average power for each time interval (i.e. import energy – export energy multiplied by two). Gridimp and Orange Power provided meter data for the ISP's where FlexOrders were issued in 100% and 96% of cases respectively. This data allowed us to calculate the volume of flexibility that was delivered by comparing it against their D-programme baseline, which they provided day-ahead.

In order to investigate the accuracy of the aggregator baselines, aggregators provided additional meter data for all days between 01/05/22 and 30/06/22. These extra days allowed us to generate a historical baseline using the ENA's Baselining tool as described in more detail in Section 4.4.

3.2. TRIAL SUMMARY STATISTICS

3.2.1 Scope

The purpose of this section is to provide an overview of the scale of the trial to date, including the number of messages that have been exchanged and the volume of flexibility that has been delivered. We also draw comparisons between the results from Phase 1 and 2 of the trial.

3.2.2 Results and Analysis

We have summarised the results of the trial based on the messages exchanged between the DSO and aggregators in the USEF Validation Phase (Table 9). These are principally FlexRequests, FlexOffers and FlexOrders. The DSO has requested flexibility, via a FlexRequest, 446 times throughout the trial across all congestion points (211 in Phase 1 and 235 in Phase 2). During Phase 2, the DSO has requested a larger range of flexible power compared with Phase 1, including FlexRequests of 1000 kW and has requested more flexibility overall compared because of the addition of the 11kV feeders to the list of congestion points.

As in Phase 1, the trial has continued to see more FlexOffers being made by aggregators than FlexRequests. More significantly, 93% of FlexRequests received at least one FlexOffer which demonstrates the reliability of aggregators to offer flexibility when the DSO requests it.

The number of FlexRequests that are followed up by a FlexOrder is governed by the simulation schedule and the DSO's operational decisions. 188 FlexOrders were issued in Phase 2, which provides a large sample to explore characteristics such as the reliability of aggregators being able to deliver flexibility ordered.

Aggregators have continued to overdeliver on the ordered flexibility, as was in the case in Phase 1 (shown in the "Total Flexibility Realised" row). To avoid this overdelivery from masking what is happening at other times in the trial, the "Total Flexibility Delivered" has been calculated by capping the response at 100% of the FlexOrder power. Accounting for this, the "delivered" flexible energy makes up 65% of the ordered energy.

Finally, the total utilisation payments in Phase 2 has exceeded Phase 1 due to the additional congestion points added and the trial experimented with different volumes of flexibility.

Table 9 FUSION Phase 2 Trial Summary Statistics

Message	Statistic	Phase 1	Phase 2	Phase 1 & 2	Comments
FlexRequests	Total number of FlexRequests	211	235	446	
	Range of FlexRequest Power Requirements	5-500 kW	0.4-1000 kW	0.4-1000 kW	
	Total Flexibility Requested	28.5MWh	79.5 MWh	108.0 MWh	Averaged per ISP
FlexOffers	Total number of FlexOffers	268	307	575	
	Number of FlexRequests with at least one offer	202	215	417	
	Total Flexibility Offered	29.6 MWh	77.7 MWh	107.3 MWh	
FlexOrders	Total number of FlexOrders	153	188	341	
	Total Flexibility Ordered	17.9 MWh	25.1 MWh	43.0 MWh	
	Total Flexibility Delivered	15.9 MWh	16.2 MWh	32.1 MWh	Capped at 100% of FlexOrder
	Total Flexibility Realised	23.8 MWh	36.1 MWh	59.9 MWh	Not capped at 100% of FlexOrder

	Total utilization Payments for Flexibility Delivered	£7109	£11,200	£18,309	

A new aspect in Phase 2 of the trial is the addition of the 11kV feeders as congestion points. We have therefore isolated the summary statistics for these sites and compared them with congestion points at the two primary substations. The results show that while the primary substations still involve the majority of flexibility that is ordered, there is sufficient data for the 11kV feeders to gain insights into how the trial has performed at this network level.

Table 10 FUSION Phase 2 Trial Comparison Between Primary Substation and 11kV Feeders

Message	Statistic	Primary Substations	11kV Feeders
FlexRequests	Total number of FlexRequests	126	109
	Range of FlexRequest Power Requirements	50-1000 kW	9-540 kW
	Total Flexibility Requested	63.2 MWh	16.3 MWh
FlexOffers	Total number of FlexOffers	193	114
	Number of FlexRequests with at least one offer	120	95
	Total Flexibility Offered	48.8 MWh	28.9MWh
FlexOrders	Total number of FlexOrders	120	68
	Total Flexibility Ordered	22.3 MWh	2.8 MWh
	Total Flexibility Delivered	14.5 MWh	1.7 MWh
	Total Flexibility Realised	30.9 MWh	5.2 MWh
	Total utilization Payments for Flexibility Delivered	£10131	£1069

3.2.3 Learnings and Conclusions

The scale of the trial has increased in Phase 2 as more flexible assets and congestion points have been added. The DSO has experimented with requesting smaller and larger volumes of flexibility compared with Phase 1 including up to 1000 kW. In response the aggregators have continued to offer flexibility to FlexRequests in the vast majority of cases (92%). The trial has, therefore, been generating sufficient data to explore the trial's learning objectives in more detail.

The aggregators have continued, in aggregate, to overdeliver on the volume of flexibility that is ordered despite changes to the FSA to reduce the penalties for underdelivery. The explanations for this are explored further in the next section however it is important to note that from a network management perspective overdelivery is not always desirable. One of the risks of over delivery of flexibility is that it becomes more difficult to counteract the action to neutralize the effect on the system balance (the so-called redispatch); redispatch is a necessary part of any activation of flexibility as part of a constraint management service that is not being examined in this trial. In the trial, aggregators were not penalised for overdelivery in the FUSION trials, but neither are they remunerated for it.

3.3. RELIABILITY OF DELIVERY

3.3.1 Scope

The purpose of this section is to outline whether the aggregators have been able to deliver flexibility when it is ordered and to identify patterns and trends in how and when flexibility is delivered.

3.3.2 Results and Analysis

Orange Power have continued, as in Phase 1, to overdeliver on the ordered flexibility volume (Figure 8): in the case of the 11kV feeder "18612", the average overdelivery is 15 times the ordered flexibility. In the aggregator interviews, Orange Power confirmed that this is by design as they are compensating for the known inaccuracy of their baseline, to ensure that they deliver at least 100% of a FlexOrder. They are also having an issue with the time it takes for data showing how they assets are being used to become visible. For some assets this is within 5 seconds whereas for others it can take up to 1 day. This delay has also meant they have continued to be conservative by overdelivering on flexibility.

Gridimp have experienced different challenges in Phase 2 of the trial. At St. Andrew's primary substation, they have consistently delivered negative flexibility (i.e. their generation has decreased or demand has turned up) (Figure 8). Gridimp's feedback was that they have been focusing on getting more flexible assets enabled because they have not had enough assets available to meet their contracted availability volume. This focus has meant that they have dedicated less time to ensuring their baseline is accurate, which has made it challenging to determine how much flexibility Gridimp are delivering. Therefore, the unreliability of their baseline explains the reason for the negative average delivered flexibility. At Leuchars, Gridimp are on average delivering 81% of the FlexOrder power.

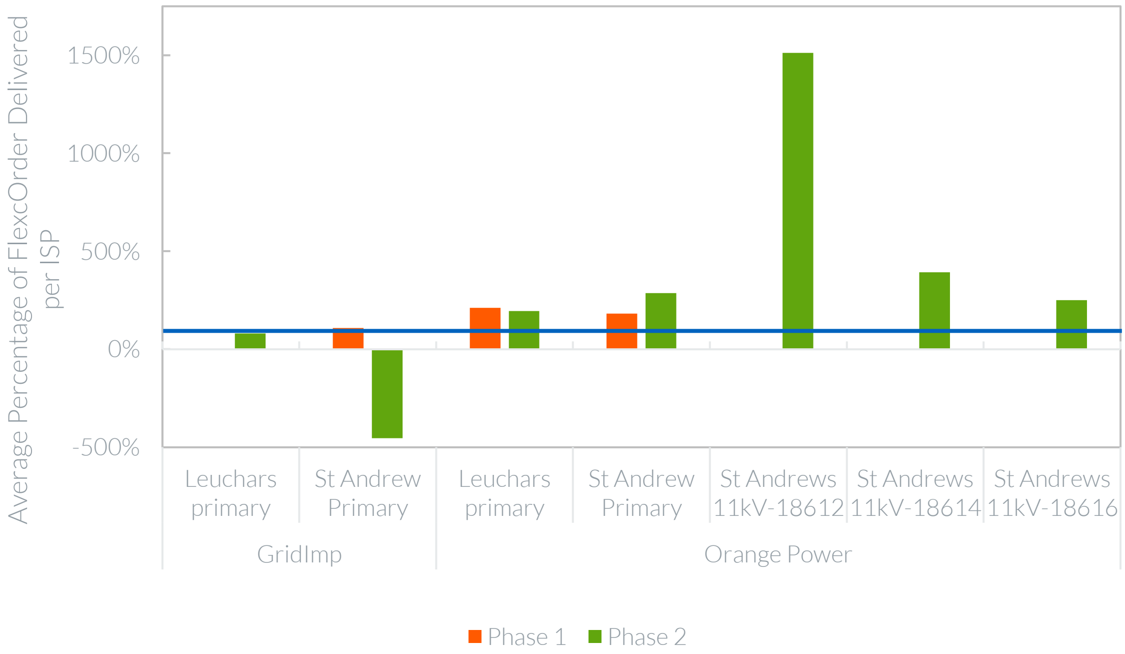


Figure 8 Average Percentage of FlexOrder Power Delivered Per ISP for Phase 1 and 2

More can be understood about the performance of each aggregator by plotting the response to each FlexOrder over the trial period (Figure 9). The results show that in June and July, Gridimp underdelivered significantly at St Andrews. The reason for this is that the baseline that was provided day-ahead, consistently suggested that their CHP plants would be generating electricity. Whereas the outturn showed that their assets were a net demand on the substation. The settlement, which is calculated by subtracting the baseline from the outturn, therefore showed a large increase in demand when the flexibility was ordered. Gridimp have learnt from this and have updated their baseline methodology to make it more reflective of the operation of their assets, therefore we expect an improvement to these results in the next analysis of the trial.

The results also show that Gridimp were far more successful at delivering flexibility at Leuchars however, they have not offered flexibility in response to a FlexRequest since 17/06/22.

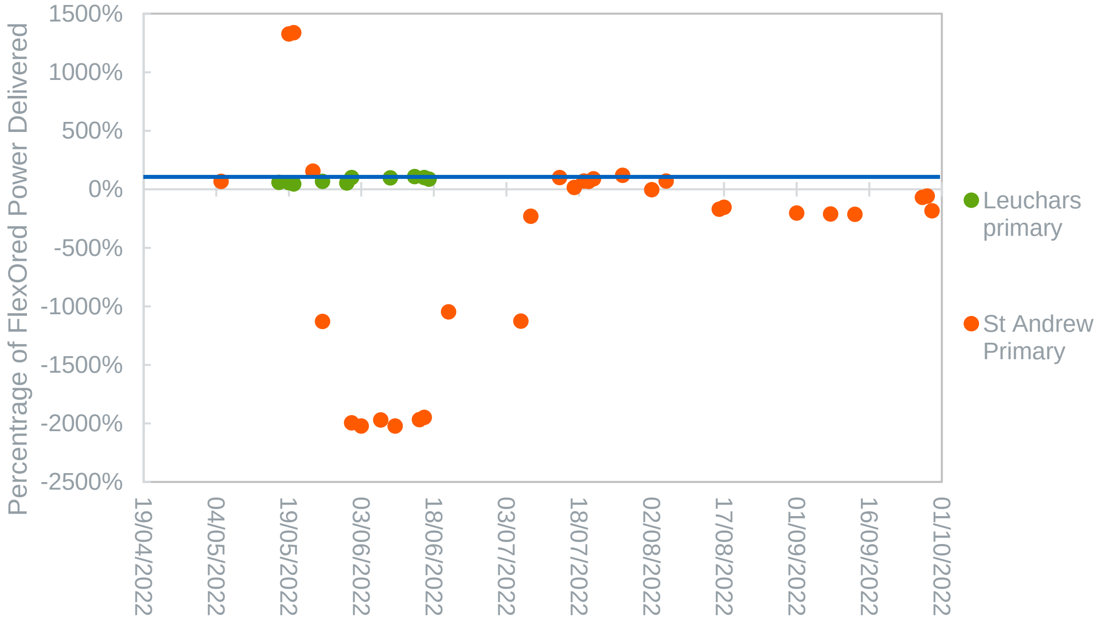


Figure 9 Average Percentage of FlexOrder Power Delivered Per ISP by Gridimp in Phase 2

The plot of Orange Power's delivery over time shows the variation between the primary substations and the 11kV feeders (Figure 10). The results show that Orange Power have tended to over-deliver more frequently at the 11kV feeders than at the primary substations. The delivery for Leuchars and St Andrews primary has been consistently closer to the 100% than at the "18612" feeder in particular. The reason for this is a combination of the inaccuracy of the aggregator baseline (discussed in Section 4.4) and that Orange Power have fewer of their assets connected to each feeder making it difficult to predict what the behaviour of them is going to be. This means that they are very conservative when dispatching the flexibility, which has led to them overdelivering.

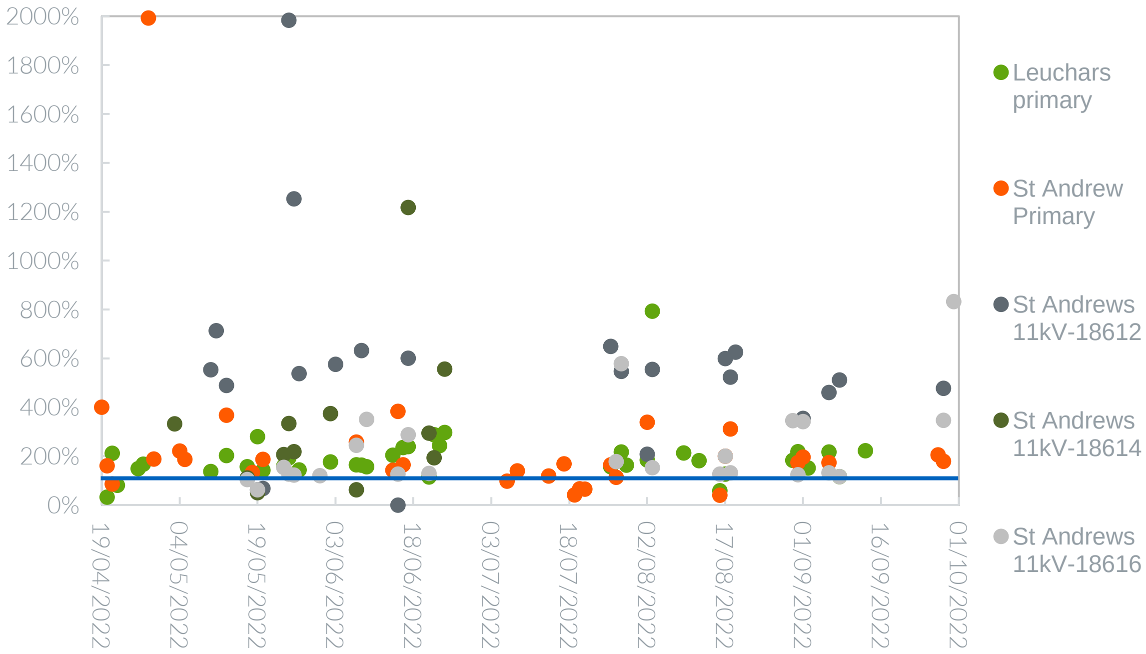


Figure 10 Average Percentage of FlexOrder Power Delivered Per ISP by Orange Power in Phase 2

Our analysis also investigated the correlation between the time of the activation window and the percentage of the FlexOrder that was realised (Figure 11Error! Reference source not found.): The aim was to understand whether aggregators were more accurate at delivering the agreed amount of flexibility at different times of day. The results show that aggregators have been marginally more likely to deliver closer to the FlexOrder power outside of the availability windows (before 11am and after 3pm). It is worth noting that the sample size for these cases is smaller as the majority of FlexOrders (60%) were issued within the main availability window. For larger portfolios of flexibility, the reliability of delivery is an important factor in determining the volume of flexibility that is required. Awareness that this may change throughout the day is therefore a useful insight from the trial.

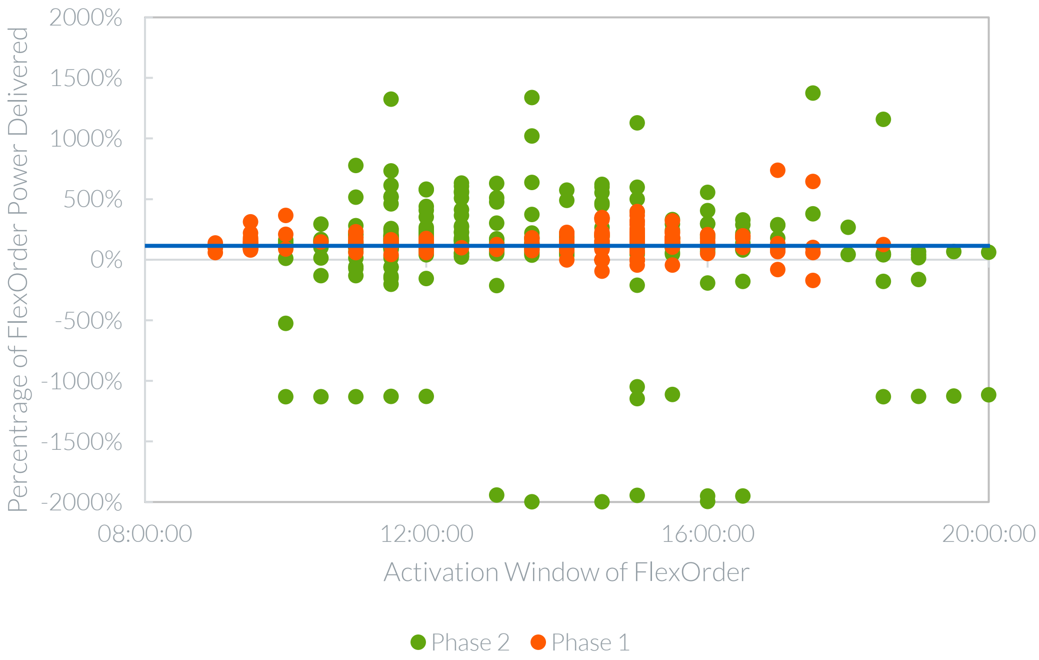


Figure 11 Percentage of FlexOrder delivered by aggregators by Time of Day for Each ISP in Phase 1 and 2

We also analysed the impact of the notice time, which links to the different services, between the issue of the FlexOrder and the activation of flexibility. The sustain service has the longest notice time, since the flexibility is requested day-ahead, whereas the secure and dynamic service have a notice period of 30 minutes and 15 minutes respectively. Overall, the results demonstrate that the notice time had a small impact on the accuracy of the FlexOrder delivery. Figure 12 shows more clustering around the 100% delivery value for FlexOrders that were issued day-ahead compared with intra-day. As discussed previously, the large outliers that can be seen are due to issues with the accuracy of the aggregator's baseline: the fact that they are clustered in a horizontal line represents how the underlying assumption about whether the CHP was on or off was not correct.

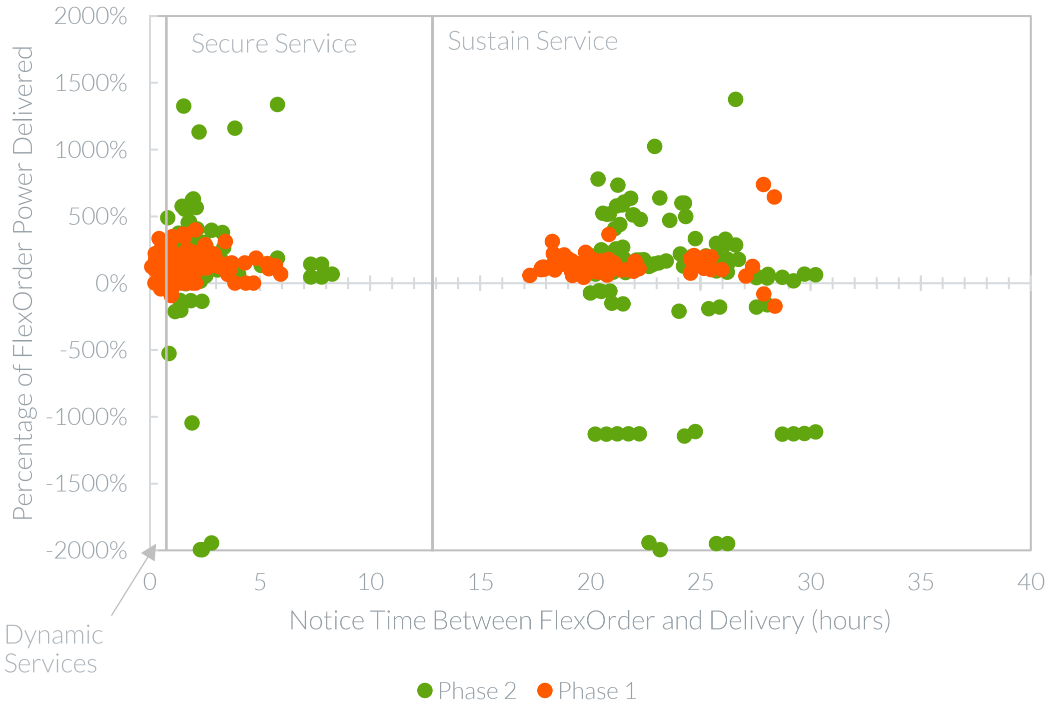


Figure 12 Percentage of FlexOrders Realised by aggregators by Notice Time Between FlexOrder and Utilisation for Each ISP in Phase 1 and 2

The reliability of the different service types was also explored, which showed that aggregators were 4% more reliable at delivering FlexOrders in a secure test case than a sustain. The reliability of the Dynamic FlexOrders was the best at 81% however it is worth noting there were only 21 cases over both phases of the trial therefore the sample size is relatively small. Nonetheless, the fact that the service types with the smaller notice times between FlexOrder and delivery showed better results with respect to delivering FlexOrders, is a useful observation from the trial. It suggests that delivering flexibility closer to real time FlexOrders would still achieve good results.

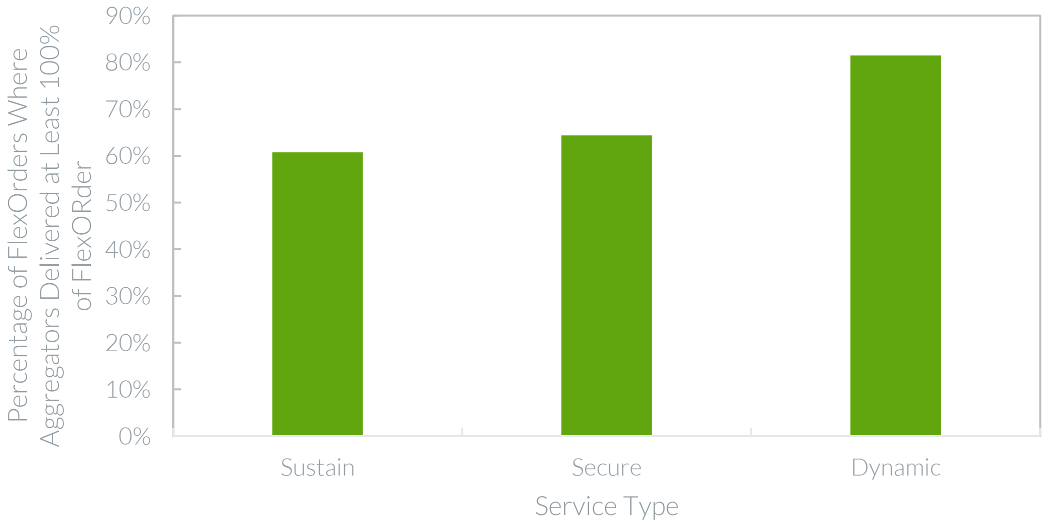


Figure 13 Percentage of FlexOrders Where Aggregators Delivered at Least 100% of FlexOrder Across Both Trial Phases

We calculated the reliability of day-ahead and intraday FlexOrders to determine whether one was more reliable (Figure 14). Our results show that flexibility that was ordered day-ahead was more reliably delivered than intraday across all congestion points (except for Gridimp at St Andrews which, as described previously, had issues with the accuracy of the baseline). Orange Power expressed a preference for day-ahead FlexOrders as this gives their customers more time to respond, which may explain the difference between day-ahead and intraday results. Gridimp stated that their CHPs have the longest ramp time (15 minutes), therefore in instances where the FlexOrder was sent less than 15 minutes in advance there may be some impact from ordering flexibility intraday. These cases were caused by an operator error and are not expected to happen in the future. This occurred only four times in the trial, and is unlikely to have a large impact on the results. In general, Gridimp, stated that their system is fully automated, so there should not be a significant difference between intraday or day-ahead. Therefore, we will continue to study this as the trial develops to see whether additional data supports this trend.

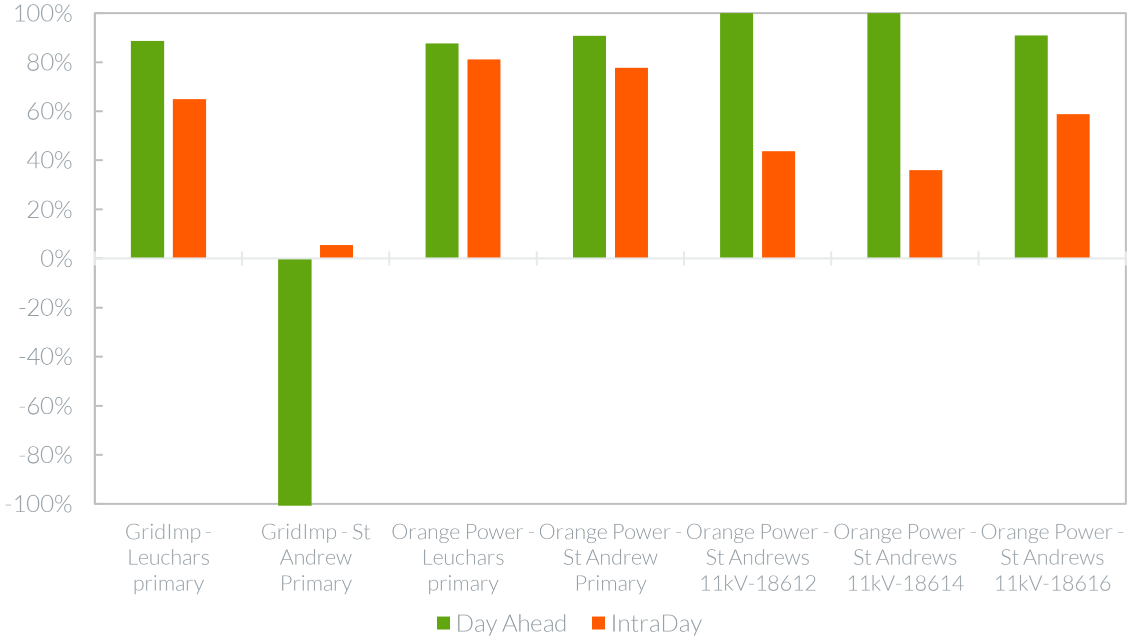


Figure 14 Comparison of Day Ahead and Intraday Reliability in Phase 2

Finally, we calculated the overall reliability in Phase 2 at the different congestion points (Figure 15Figure 14). The results show that all congestion points achieved a reliability of 73% or higher at every congestion point except Gridimp at St Andrews. Overall, aggregators were able to reduce their demand in response to a FlexOrder in 86% of ISPs, which is down from 97% of ISPs in Phase 1. The reason for this is largely part due to the performance of Gridimp at St Andrews due to the inaccuracy of their baseline.

Figure 15 Phase 2 Reliability Calculated by Dividing Delivered Power (capped at 100% of FlexOrder) by ordered power

3.3.3 Learning and Conclusions

The trial results show that aggregators have achieved reliability of 73% or above at all congestion points except for Gridimp at St Andrews. When focusing on Orange Power, this increases to 86% (Figure 15).

We have discussed the method used to calculate reliability with the TRANSITION project, another flexibility market trial based in Oxford. Their calculation method followed the following equation:

$$Reliability_{TRANSITION} = \frac{Hours\ available}{Hours\ contracted}\ x\ \frac{Flex\ delivered}{Flex\ ordered}$$

There is no mechanism within USEF for aggregators to indicate the number of hours their assets are available therefore it is not possible to make direct comparisons between the two trials. Instead USEF focuses on aggregators response to requests for flexibility as the primary measure of flexibility.

Results displayed in this section have shown that aggregators are being more conservative by activating more flexibility when dispatching a smaller number of assets. This conservatism is to ensure that they achieve at least the ordered flexibility and is demonstrated most clearly at the 11kV "18612", which has the highest over-delivery of all congestion points.

The outlier in terms of reliability is Gridimp at the St Andrews primary substation. The reason for this is the inaccuracy of the baseline, which is affected heavily by whether the CHPs are in an 'off' or 'on' state. Due to the inaccurate baseline, the results give the impression that the aggregator has either increased demand or decreased generation in response to a FlexOrder. However, if the baseline had correctly accounted for whether the CHPs were on or off, then the delivered flexibility would have shown a significantly improved performance. This finding emphasises the importance of having a reliable baseline from which to measure the response. The baseline accuracy is discussed in more detail in Section 4.4.

3.4. OFFER PRICES

3.4.1 Scope

The purpose of this section is to provide an overview of the prices of FlexOffers that aggregators have sent in response to FlexRequests. Our analysis includes the distribution of offer prices for each aggregator and the relationship between offered power and offer price. The section provides insights into the pricing strategies adopted by the aggregators.

3.4.2 Results and Analysis

Table 11 below summarises the minimum, maximum and average offer price for Phase 2 of the trial at each substation by aggregator. Overall, Table 11 shows that Gridimp's offer prices have remained at or close to the contract price caps for utilisation during the service window. Gridimp confirmed this in their interviews as much of their activities are automated. The only exception was during the St Andrew's golf tournament where they offered a maximum offer price of £0.8/kWh as a free bid.

Table 11 Flexibility Offer Prices from the Phase 2

Aggregator	Congestion Point/Aggregator	Minimum Offer Price in Trial (£/kWh)	Maximum Offer Price in Trial (£/kWh)	Average Offer Price in Trial (£/kWh)
Gridimp	Leuchars primary	0.4	0.4	0.4
	St Andrews Primary	0.4	0.8	0.45
Orange Power	Leuchars primary	0.49	0.49	0.63
	St Andrew Primary	0.49	0.97	0.66
	St Andrews 11kV-18612	0.49	0.99	0.68
	St Andrews 11kV-18614	0.49	0.49	0.49
	St Andrews 11kV-18616	0.49	0.99	0.67
	Average	0.4	0.99	0.59

[1] The values differ by aggregator but are the same for all service windows, notification periods and contract types

Results from the trial showed the majority of FlexOffers were priced between £0.4 and 0.5/kWh (Figure 16). Orange Power offered flexibility a wider range of prices in Phase 2, particularly during the St Andrews Golf tournament in July where they offered flexibility at the maximum price. At St Andrews, 45% of their FlexOffers were £0.7/kWh or above. These prices show Orange Power are utilising the increase in the price cap for free bids that was introduced after Phase 1 of the trial (from £0.5 to £1/kWh). Further analysis on how the offer prices changed due to free bids is described in Section 4.3.

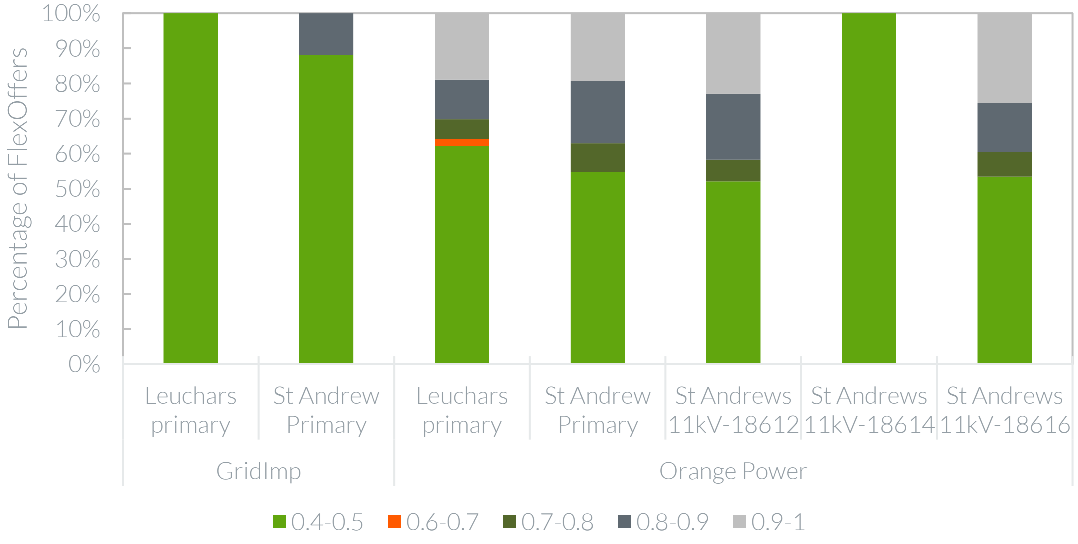


Figure 16 Distribution of Offer Prices for Each Congestion Point and aggregator

We also investigated the relationship between the volume of offered power and the offer price. The analysis showed that volumes of offered power had a small effect on the offer price (

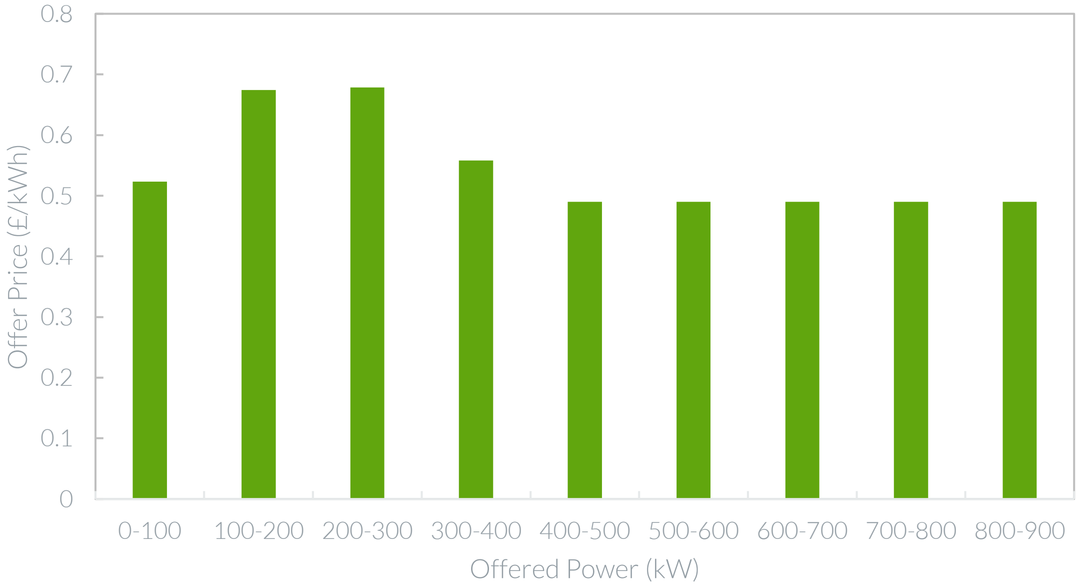


Figure 17 Comparison of Offered Power and Average Offered Price

Figure 17). However, there is insufficient data from offers below 100kW to draw firm conclusions.

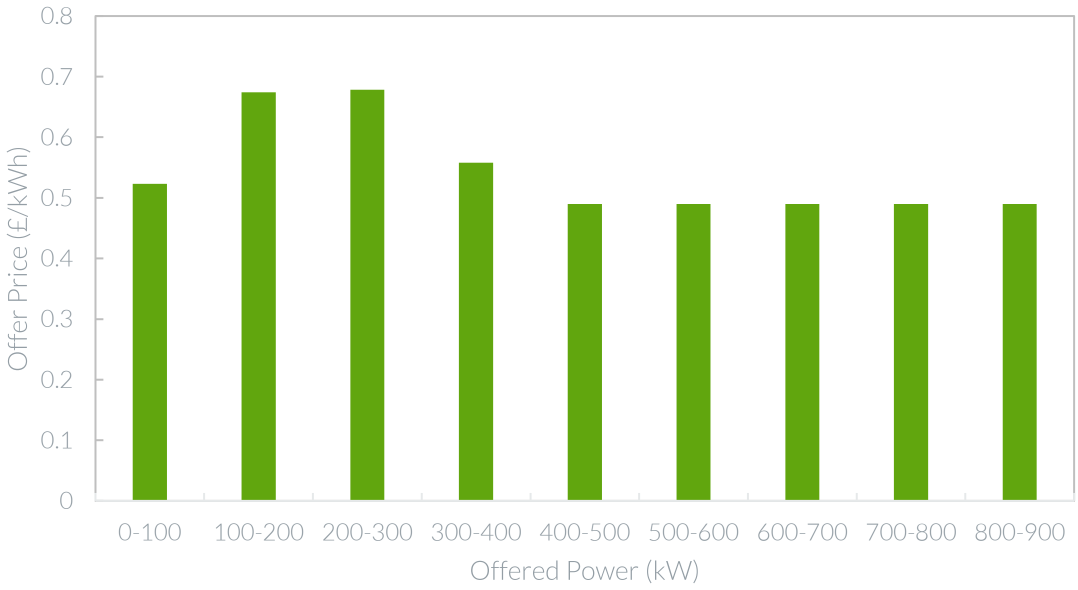


Figure 17 Comparison of Offered Power and Average Offered Price

3.4.3 Learnings and Conclusions

This section has demonstrated that offer prices have remained relatively constant throughout Phase 2 of the trial and no real patterns or strategies have emerged regarding the pricing of utilisation. Gridimp's offer prices have remained either very close to or at the contract price caps for utilisation whereas Orange Power have offered flexibility at a wider variety of prices.

The price that aggregators are paid for availability continues to be higher than that for being activated. One of the reasons for this was to encourage participation in light of the high wholesale electricity prices at the time of the trial. The other reasons were to cover the capital costs associated with applying USEF and to attract new aggregators to the area to ensure that at least two were able to participate in the trial. Feedback from Gridimp was that due to the increased incentive of the availability payments against utilisation, their focus has been on this rather than on varying the offer prices and providing free bids.

4. Trial learnings

4.1. COMMON REFERENCE OPERATOR (CRO)

4.1.1 Scope

The Common Reference Operator (CRO) is responsible for operating the common reference (CR), the repository that contains detailed information on network congestion points, associated connections, and active aggregators in those connection points. The CR enhances transparency by allowing aggregators to get the information on the congestion points where they are active (and only those for confidentiality and privacy reasons). It also allows DSOs to get visibility on the aggregators operational at their congestion points.

4.1.2 Methodology

For this objective, the following CRO questions are answered based on the interviews with the aggregators and DSO:

- Who should perform the CRO role?
- Should there be one Common Reference (CR) for GB?

How to integrate with grid topology system?

In addition, FUSION explores SP Energy Networks' and the aggregator's experience when fulfilling the CRO role and interacting with the CR, assessing the benefits they access and challenges they encountered in comparison with using other platforms. Finally, potential next steps and suggestions for improvement are addressed.

4.1.3 Results and Analysis

- Throughout the FUSION trial, SP Energy Networks has fulfilled the Common Reference Operator role by populating the CR section of the platform according to the contracts. SP Energy Networks' experience has been satisfactory, not having experienced any challenges.
- Aggregator experience: Aggregators have had to interact with the Common Reference platform at the beginning of trial phases 1 and 2. Aggregators consider it advantageous as it serves them to provide their information and get input back on the congestion points where they operate. Nonetheless, aggregators provide some suggestions to be considered for the mid- and long-term.
    - Currently, providing the necessary information is a quick step for aggregators; however, it is expected to be more significant and time-consuming when there is a wider program with more assets.
    - Orange Power proposes to explore the addition of two extra fields to the Common Reference.
        - Firstly, the type of services, including both the services that the DSO may need in this congestion point, as well as the services that the aggregator can offer.
        - Secondly, any extra information that could help with the ordering process of an asset, including the congestion point location, the entity addresses and time and location of the products. OP suggests clarifying how the entity address, the GSP and the MPAN are linked and have them be aligned to have a clear common language.

SP Energy Networks agrees this would be worth further exploring how to make data recognisable and standardised, highlighting the need to be compliant with data protection policies.

- Gridimp indicates that currently, identifying the connection point IDs used in USEF to form the trades is done manually through Scottish Power by the aggregator providing them with the MPAN. Gridimp suggests exploring how this step could be done within the CRO to eliminate a step in the process. It would also help onboard clients more quickly and carry out the settlement process, reducing operating costs and resulting in more flexibility being unlocked.

- Regarding expanding the CRO role to national level, Orange Power believes that having one location pooling all the DSO requests may be beneficial to access value stacking opportunities.
- CR at DSO level: USEF, at the moment, only includes DSO requests. Keeping this at DSO level is considered useful, as long as there is also coordination with ESO requests to potentially further enhance value stacking. OP suggests coordinating with the ESO Local Constraint Market (LCM), as the ESO is aiming to have low granularity and conflict or mismatch should be avoided.
- Cybersecurity: OP highlights that, compared to other platforms, the Common Reference has a security advantage with encryption, that it covers both DA and intraday.
- Location signal: It also provides a location signal if the aggregator has connections under the relevant congestion point across different DSOs.
- Grid topology: Phase 2 of the trial explored three feeders in St. Andrews as well as the two primaries of St. Andrews and Leuchars tested in phase 1. What happens in terms of constraints at primary level affects the congestion in the feeders and vice versa. Therefore, congestion in one could be solved by activating flexibility in the other. Not accounting of what happens at feeder level to assess the primary as vice versa is a practical limitation. This issue is further described in Section 4.6.

4.1.4 Conclusions and Learnings

Phase 2 of the FUSION trial highlights the benefits of the Common Reference:

- Experience of both SP Energy Networks, fulfilling the Common Reference Operator role, as of the aggregators as users, has been positive, as it facilitates access to the information on network congestion points, associated connections and active aggregators in those connection points.
- Aggregators highly appreciate the security of the platform and encryption.
- Maintaining the CR at DSO level is considered beneficial. Further coordinating with ESO requests could unlock value staking opportunities.

4.1.4.1 Next steps for this objective

Until the end of the trial period, it is recommended to continue gathering learnings regarding the experience fulfilling the role of common reference operator and using the common reference platform.

4.2. DSO DATA TRANSPARENCY

4.2.1 Scope

This subsection aims to explore how data transparency can be enhanced and the consequences this would have, understanding data as network, market and dispatch data. Aggregators have to access and handle significant data on congestion points, market rates, trades, events, assets, and sites, among other things.

4.2.2 Methodology

For this objective the following questions regarding data transparency are answered based on the interviews with the aggregators and DSO:

- To what extent can FUSION deliver transparency of the following data, and what could be done to enhance this? Network data (constraints etc), market data (costs etc) and dispatch data (events duration etc).
- How to enhance interaction with market players – including privacy aspects?
- Would sufficient transparency lead to more or less flexibility being activated by the DSO?
- Would sufficient transparency lead to more or less flexibility being unlocked and offered by the AGR?

In addition, the FUSION project explores if the trial participants had encountered any issues sharing or accessing the data and how this could be improved. Finally, reliability, accuracy and traceability of the data needed is assessed, as well as how it can be enhanced and its implications.

4.2.3 Results and Analysis

Aggregators could access two competitive processes during phase 2 of the FUSION trials; they can offer their flexibility through 1. availability contracts or 2. day-ahead or intraday competitive bidding for utilisation contracts. Having full data transparency is key to

- The transparency of the data throughout the process has been perceived as follows:
    - Orange Power is currently satisfied with the level of transparency offered. However, OP suggests that, even though at the moment it would be overengineering, in the mid- or long-term, there could be a transparency forum to be carried out on a weekly basis or more information shared on the website to further enhance transparency.
    - Gridimp considers the tender process transparent, nonetheless, would like to have the bid selection for utilisation contracts be clearer. This would reduce their uncertainly and would be helpful when communicating and onboarding new clients.
- Aggregator data sharing: Aggregators have not faced issues when sharing data.
- Aggregators are encountering some challenges accessing data.
    - OP however encountered an internal issue aligning APIs with the code as there are many manufacturers using the submeter, meaning that there is a need for updates every time one of them changes their API.
    - Gridimp indicated that getting the MPAN data from residential assets is currently a tortuous process and getting the consumer to consent to the process is a challenge.
    - Gridimp stresses the importance of accessing the customer data and details regarding what assets there are and where they are, as they encountered the issue of some of the assets in the original list not being operational, and further assets that were not originally in the list being discovered.
- SP Energy Networks has not experienced any significant issue sharing or accessing data during phase 2 of the trial. Previously, there had been some issues where, for instance, the metering data was rejected and had to be resubmitted by the aggregator, or the FlexRequest was sent but the aggregator did not receive it. These technical issues were resolved and have not been encountered during this trial period.

- Interaction with other market players and privacy concerns:
  - Orange Power currently does not face privacy concerns, as what is established in the ICC and GDPR is strictly followed. OP informs upfront of what data will be shared with the grid when participating in an event to prove delivery. Information is always shared at portfolio level, without sharing any information that could identify any address, meter, or consumer. Only sharing information at portfolio level is recommended to reduce privacy concerns.
  - Gridimp also proactively provides information on data sharing and handling to its clients. It has highlighted that the information that USEF requires is in line with what they need in BaU; therefore, does not bring any challenge.
  - SP Energy Networks, currently fulfilling the common operator role, does not face data privacy challenges, however, reflects on what would be their concerns if a separate entity was to act as a CRO. Despite USEF being encrypted, there might be sensitive data, therefore, there would have to be a thorough due diligence process to ensure how the data is stored, handled and processed.
- Data reliability and accuracy:
  - OP carries out pre-processing of the data to remove noise and flag potential issues with the data coming from the submeter or the API despite not having experienced meaningful issues with data accuracy. There have been minor issues with the registering of data of individual assets that have now been resolved. For more detailed information on data reliability and accuracy, please refer to Section 3.3 and Section 4.7.
- Trackability and traceability: In general, aggregators were satisfied with the data trackability and traceability throughout the trial.
  - Nonetheless, OP signalled that from the asset side, not all APIs were available from the manufacturers and suggested having to make the API available for the large assets for the aggregators to access.
  - Gridimp in general was also satisfied, however indicated that mapping the MPAN to the connection was time consuming and not easily traceable.
- OP mentions that, at the moment, National Grid system of utilisation payments only is removing the barrier for residential participants by rewarding the amount they contribute regardless of how accurate it is. The FUSION trial, in comparison, has availability payments, so assets should be available. However, currently aggregators, regardless of the size of their portfolio, would have to take on the responsibility by finding a controllable asset like a CHP to compensate for a deviation of the residential assets. OP suggests exploring how, in the future, this responsibility can be covered with the DSO, because despite not being commercial, it would be an important step at making the residential customers more flexible.
- Transparent communication exchange: DNV identified that aggregators find identifying the service requested challenging and hard to automate, as this process is hindered by the different services having different service windows. This results in aggregators sometimes not identifying which bids are free bids and which are not.
  - Gridimp indicates that adding information of the service type to the FlexRequest could be useful to implement in the long-term.

4.2.4 Conclusions and Learnings

- Aggregators and the DSO did not have notable issues accessing or sharing data in the FUSION trial.
- Currently, the FUSION trial participants are not facing data privacy concerns. If the CRO role were to be transferred from SP Energy Networks to a separate entity, a thorough due

diligence process would have to take place to ensure the data is stored, handled and processed appropriately.

- From the two competitive processes with which aggregators can offer flexibility to the DSO, aggregators found availability contracts transparent, however, had **questions regarding the selection of utilisation bids** for certain lesser common cases.

Next steps for this objective

- The metrics used when selecting FlexOffers are volume and cost. DNV suggests **sharing illustrative examples of how these metrics are used** to determine the ranking of the bids, particularly for the less common cases where, for example, there is a large volume of flexibility requested, or the timing is unusual, for instance, starting inside the service window and lasting past this window.
-

4.3. FREE BIDS

4.3.1 Scope

Free bids are flex offers which aggregators send in response to a FlexRequest from the DSO, that is either outside of their availability window or above their contracted power. Free bids only receive a utilisation payment.

During phase 2, free bids were trialled in the following test cases:

- 1.2 - Secure DSO Constraint Management (pre-fault) – Free Bid + Order / No Order
- 2.3 - Dynamic DSO Constraint Management (post-fault) - Free bid + Order / No Order
- 2.4 – No fault outside availability window - Free bid + no Order
- 3.2 - Sustain Peak Management - Free bid + Order (when possible)

These test cases correspond to free bids because the DSO requests flexibility from the aggregators at times outside their availability windows. At the same time, it should be noted that the USEF concept of free bids primarily focuses on the principle that (other) aggregators with a framework agreement with the DSO but with zero availability contracted (e.g. because they primarily operate non-firm resources) are allowed to respond to FlexRequests alongside aggregators with availability contracts, thus stimulating competition. This principle could not be tested within the trial.

4.3.2 Methodology

This objective builds on the analysis carried out in the ITLR2 report and aims to answer the following questions based on the trial results and interviews with the aggregators and DSO:

- Which assets can participate in DA/ID congestion management that cannot be considered firm capacity?
- What is the effect on the liquidity / activation prices / DSO costs?
- How could assets that have no firm commitment to DSO services, participate in ESO services? What would be the positive impact of this kind of value stacking to whole system optimisation and carbon reduction?
- How can the business case of FSPs operating these types of technologies improve, when they have access to this additional revenue stream? Can we expect that this will lead to more (residential) AGRs participating in DSO products?

In addition, this section describes how aggregators perceive free bids and how they have treated them, as well as changes during Phase 2.

4.3.3 Results and Analysis

Phase 1 background

In the previous ITRL, it was concluded that:

- Aggregators perceived that the free bid price cap was too low to encourage participation and hence all bids were submitted at (close to) the price cap;
- Aggregators found it challenging to identify free bid requests; and
- The trial would explore how to differentiate the submission of normal bids (under normal bids price cap) and the submission of free bids (under free bid price cap) by aggregators.

Phase 2 changes

To respond to the previous learnings, in phase 2:

- The trial increased the number of free bid requests to create a more solid base on data for this type of request;
- FUSION, in collaboration with Gridimp, put forward a change request to SHAPESHIFTER to include an attribute on "service ID" in flex requests that could help to not only identify the service requested but also perhaps whether free bids would be accepted;
- The FSA increased the price cap of free bids to 1) explore the real cost of free bids and 2) to reflect the increasing energy prices at the beginning of 2022;
- On several occasions, the DSO communicated in advance to aggregators that they could submit free bids to a particular request (e.g. planned maintenance, St. Andrews tournament); and
- The trial explored the possibility to submit several flex offers (with normal bids and additional free bids); however, this was not possible due to limitations in the FFP platform.

Free bid treatment

The conversations with aggregators revealed that aggregators do not pay careful attention to this mechanism. The reason for this is mainly because there are other more important issues that require fixing. For example, Gridimp indicated that, with limited resources, their focus is solving the problems on the delivery of contracted flexibility (CHP unavailability, commissioning of additional assets) rather than additional services.

Gridimp has signalled that since their flexibility trading is fully automated, their system does not differentiate requests within the availability window or outside the availability window. Therefore, the system respond to requests in the same manner regardless the time of the day or the requested power. The only occasions in which Gridimp has purposely provided free bids were when SP Energy Networks asked for them explicitly. Although this could be arguably fixed in the system, Gridimp has been focusing their resources on enabling assets to be able to deliver flexibility under the availability contract. The non-delivery/non-availability of flexibility under availability contract penalises Gridimp payments, and logically they are incentivised to solve this problem.

The second aggregator, Orange Power, also does not have an automated mechanism to identify requests outside the availability window. However, Orange Power has manually sent free bids in multiple occasions outside the contracted availability window, and these are normally characterised by a higher price than normal bids. This includes the occasions where SP Energy Networks requested free bids explicitly, e.g. the St. Andrews tournament. The reason for this is that this aggregator has a greater pool of enabled assets and is more actively looking for ways to get remunerated for their flexibility.

Qualitative analysis

In this analysis it is key to consider the contexts of both aggregators. Since Gridimp did not actively provide free bids, some of the conclusions are drawn based only on the experience of Orange Power.

Assets

As for phase 1 analysis, the value of free bids highly depend on the type of assets that are delivering flexibility. The assets that are considered non-firm capacity (i.e. for which the aggregator does not know long in advance whether flexibility will be available). In this case, both aggregators have non-firm capacity assets only. This means that there is a need for back-up enabled flexible capacity to ensure the full contracted availability. In the case of Orange Power, their portfolio mainly consists of residential flexibility (EV chargers, electric water heaters, heatpumps, etc), whereas Gridimp's portfolio is on the commercial sector with back-up CHPs and HVAC.

Gridimp's portfolio did not have extra capacity next to the contracted amount. Since their portfolio capacity was not firm, this caused reliability problems in their service delivery (see Section 3.3). Therefore, Gridimp did not have any extra capacity to offer in the form of free bids within the availability window.

On the other hand, Orange Power had a larger portfolio than what is contracted under the availability contract. The reason for this is to ensure long-term availability with non-firm capacity. Like in phase 1, this means that in the short term there might be more flexible capacity available than what has been contracted.

What did aggregators do with this extra non-firm capacity?

Although the aggregators perceive that the free bid mechanism is useful and helps to optimise non-firm flexible capacity, they did not fully make use of it during Phase 2.

For Gridimp it was not plausible to focus on this while they were having issues with normal service delivery and they did not have any extra unused capacity.

Orange Power did send free bids; however, they also did not fully explore the mechanism possibilities even with the amount of extra enabled capacity. Whereas they did not express a clear reason for this in the interviews, our analysis highlights that:

- There is no clear view on the extra available capacity due to lack of short-term portfolio monitoring, which makes it challenging for the aggregator to have a detailed view on the spare capacity that is outside the availability contract. The lack of short-term portfolio monitoring is mainly due to the latency of the data (e.g. some of the sub-meter readings are only received by Orange Power's system 24 hours later).
- The utilisation prices received from free bids were not attractive enough to motivate the aggregator to investigate free bids further.
- During interviews the aggregators mentioned that the FSA does not provide enough clarity or detail on when an offer is considered a free bid and when it is considered a normal bid. However, neither aggregator explored this with SP Energy Networks during the contracting phase. This indicates again that they did not find a commercial interest in doing so.
- The aggregators are mostly focused on fulfilling their contractual obligations, since this has a significant impact on their availability payments which makes up the greatest share of their remuneration.

Orange Power indicated that to make full use of the free bid mechanism, it would be beneficial to explore segregating its portfolio in two parts, one for the unpredictable DSR (non-firm) and another for the automated customers that can be controlled. where having also availability contracts would be preferred.

Effect on business case

Even if Orange Power did not make full use of the mechanism, they still highlight that this mechanism would be very beneficial for the business case and encourage participation.

Rising the price cap for free bids in the FSA has encouraged Orange Power to send more free bids. However, even if increased, Orange Power indicated that it was still low given the current energy crisis context. This highlights once again the importance of opportunity costs when it comes to flexibility. If this flexibility can participate in other mechanisms with higher utilisation remuneration, they will bid in those markets rather than offering free bids to the DSO. Therefore, if the DSO wishes to rely on free bids for solving congestion, the bid price would need to be higher than the opportunity costs.

Within the context of the free bid cap price, Orange Power has indicated that a higher free bid price cap is not only interesting for them but also for the public. Because of the current energy context, the public has also become more energy aware, and Orange Power expects more interest with higher price caps. This also helps aggregators attracting more general customers than only early adopters.

Finally, Orange Power also highlighted the importance of free bids on value stacking. In the future, when flexibility is participating in different markets, the dynamic element of free bids will be key to enable the optimisation of flexibility across different markets.

DSO view on free bids

On the DSO side, relying on non-firm mechanisms, such as free bids, and moving away from availability contracts, is still considered a risk. SP Energy Networks believes that they would consider exploring moving into a system that was more reliant on free bids as long as there was sufficient market liquidity to make that approach statistically reliable. Further analysis would also have to be conducted regarding how aggregators perform with less availability contracts.

Quantitative insights

Aggregators priced free bids at a higher price than normal bids at all congestion points where both were used (Figure 18). All free bids were priced at the cap price or very close to it. The average free bid price is nearly double than the normal bid prices, however, the DSO does not pay any availability cost for the former.

Reliability is a key aspect for the DSO, they indicated that to incorporate the use of free bids they should prove to be sufficiently reliable. Figure 19 shows that for most of the congestion points, the reliability of free bids is very similar to normal bids. According to Orange Power, the slightly lower reliability in Orange Power's portfolio may be related to the time windows in which the free bids were requested.

Within contracted availability windows, Orange Power has offered additional flexible power in multiple occasions, in some instances the results show that they offered nearly 300kW more. Figure 21 presents the average power that was offered above contracted power for each congestion point. This means that on average, the DSO is saving 611 kW of contracted capacity. This represents 64% of the overall contracted capacity for all congestion points. Orange Power clarified that the slight difference in volumes offered in and outside the availability window is probably due to the number of assets in each location. Some assets are not reflected in the FSA (Error! Reference source not found.).

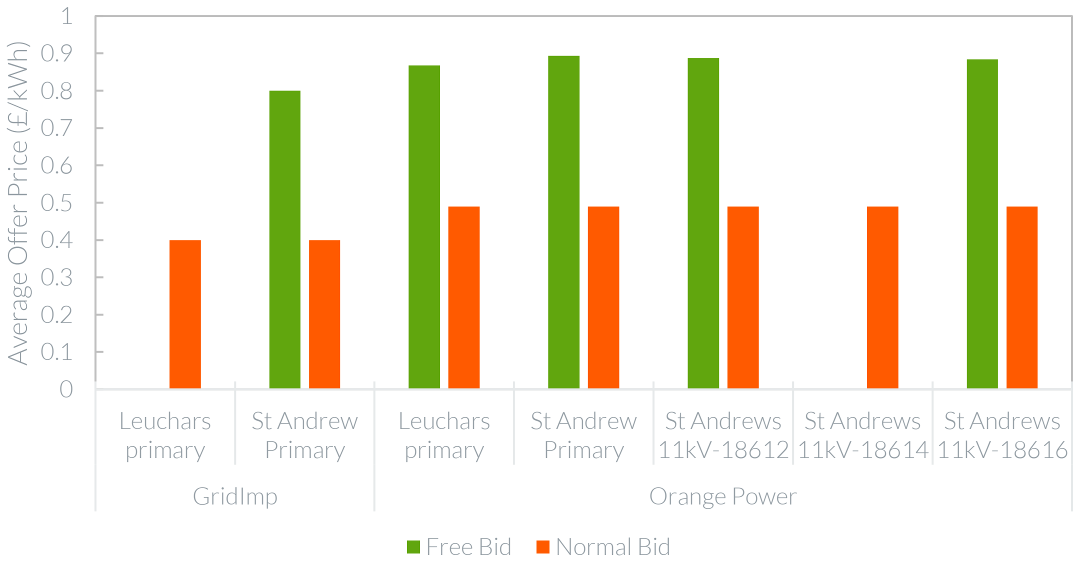


Figure 18 Comparison between offer prices of free bids and normal bids

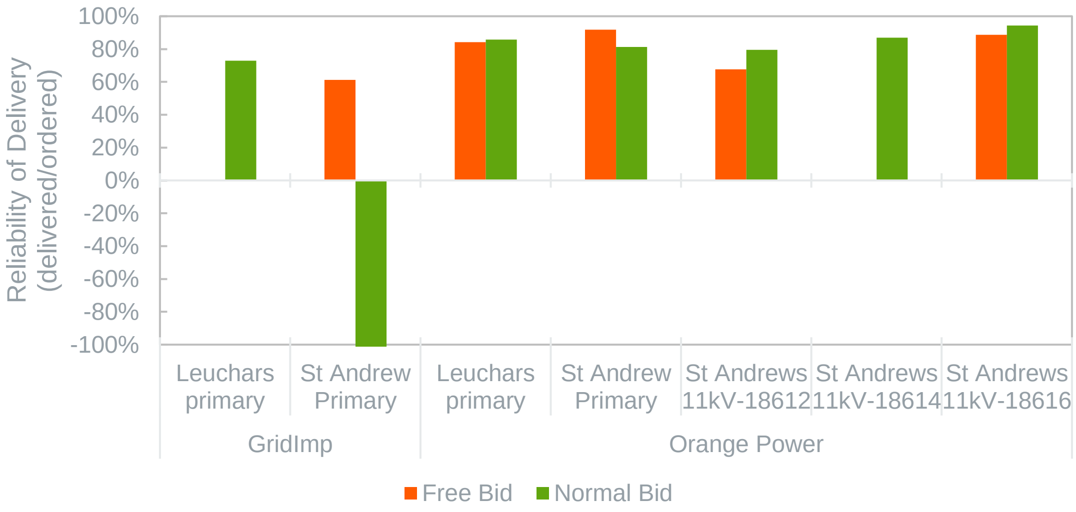


Figure 19 Comparison of reliability of delivery for free bids and normal bids

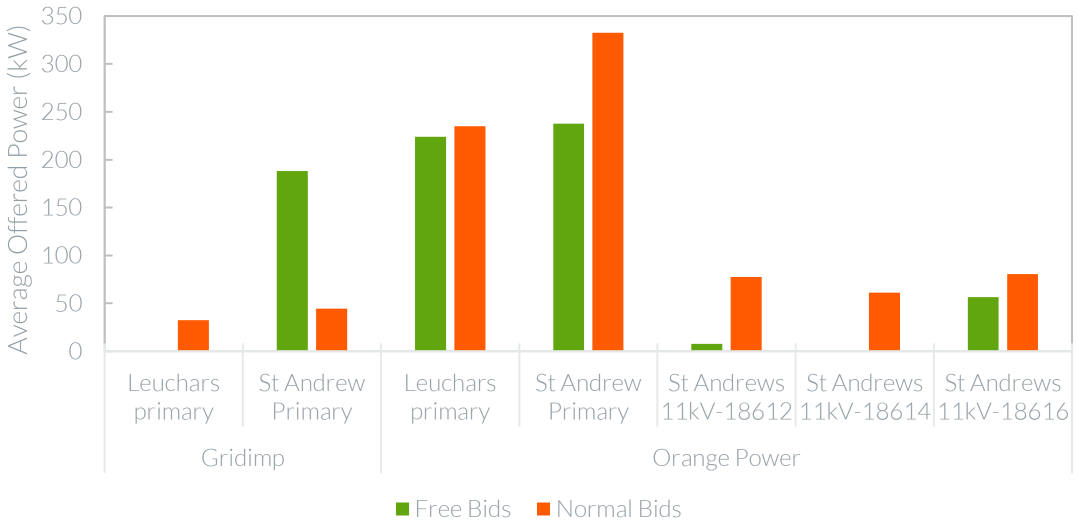


Figure 20 Comparison of average offered power for free bids and normal bids

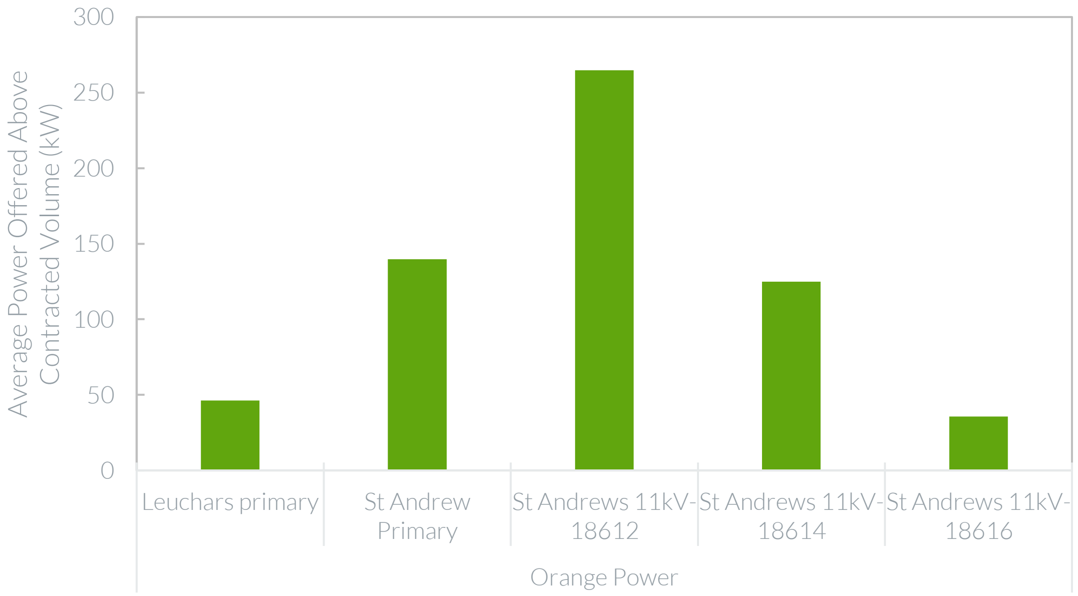


Figure 21 Average power offered above contracted volume when offer exceeds contracted volume

4.3.4 Conclusions and Learnings

- Free bidding is, according to the aggregators, a mechanism that will contribute to making more flexibility available and positively impact their business case by enabling additional revenue on non-firm capacity and value stacking in the future.
- Raising the free bids price cap in phase 2 had a positive effect in raising public interest (from aggregator's customers) on flexibility and is a good incentive to encourage participation.
- The current contractual arrangements and payment structure do not make free bids sufficiently interesting for aggregators. While aggregators appreciate the mechanism as extra revenue source, their focus is to fulfil their obligations on availability and get the payment through the availability contract.
- To participate in free bids, the aggregator needs to have short-term flexibility monitoring capabilities.

- The DSO saved 64% of the contracted capacity thanks to the extra capacity made available by the aggregator outside the availability contract (i.e. free bids).
- Even considering the potential savings, the DSO would only consider relying on free bids if there is sufficient market liquidity to make that approach statistically reliable. Ultimately, the trial has shown that the free bidding concept works but the current market and system is not mature enough yet to fully leverage this mechanism.

4.3.4.1 Next steps for this objective

- Exploring with the aggregators and DSO what would be the necessary contractual arrangements and incentives to encourage the use of free bidding.
- Estimating the theoretical value of free bids for the DSO.
- Exploring with the DSO requirements to rely on the free bid mechanism.

4.4. BASELINE DESIGN

4.4.1 Scope

DSO products for congestion management typically use historical baselines as a basis for the validation and settlement of the delivery. A recent ENA Open Networks study (Workstream 1A, Product 7 2021) suggests widening up the possibilities for FSPs, by allowing nomination baselines when the default baseline in not sufficiently accurate. The scope of the FUSION trial is to assess the performance of nomination baselines against a number of quantitative and qualitative criteria that are discussed in the "Methodology" section and provide learnings and insights to wider GB industry.

The FUSION trial is using nomination baselines (i.e. D-programmes) as prescribed by the USEF framework. Nomination baselines are the forecast of the generation or demand profile of the asset or portfolio if no flexibility activation would take place. An example of a nomination baseline is the physical notifications which are used in the Balancing Mechanism. In USEF, this forecast is determined by the Flexibility Service Provider (FSP) and sent to the DSO before a predefined deadline (e.g. gate closure). The DSO can then use this profile to calculate the deviation of the metered data from the planned profile. In general, the choice of method(s) to perform the forecast is left at the discretion of the FSP.

This section looks at the baseline accuracy, variance and bias of the D-programme submitted by the aggregator to the DSO as well as the aggregator and DSO experience using this type of baseline during the FUSION trial.

Accurate, technology inclusive, and simple baselines are an essential part of delivering and quantifying the benefit of flexibility; therefore examining the reliability of these baselines is an important part of a well-functioning flexibility market.

4.4.2 Methodology

This objective builds on the analysis carried out in the ITLR2 report, evaluate the baseline against specific criteria described below, and answer the following questions based on the trial results and interviews with the aggregators and DSO:

- Can a nomination baseline provide higher accuracy than historical? If so, under which conditions?
- Which processes are needed for this baselining methodology (information exchange, monitoring)?
- How complex is the implementation of these processes?
- Would this (additional) baseline increase the inclusivity of the congestion management products?

The baseline is evaluated against the following criteria:

- Accuracy: The degree to which the baseline is able to accurately predict energy demand. Variance will be measured by the relative root mean square of the errors (RRMSE), see Equation 4 below. Literature proposes that RRMSE of 10 per cent or less is generally considered to be 'good', and an RRMSE between 10 and 20 per cent is considered to provide 'acceptable' accuracy.[13] Accuracy is typically expressed in variance and bias:
  - Variation (or normalised variance): The degree in which the baseline error varies. Variability will be measured in normalized mean absolute error (see equation 2). In this phase, the analysis will be done only on D-programmes. In phase 2, the aim is to compare D-programme variance against other baseline types for the FUSION trial.
  - Bias: The degree to which the baseline method tends to over- or under-predict the actual metered load of the portfolio. Most programs seek baselines with zero bias; however, baselines characterised by consistent, but minor under- or over-estimates can be acceptable as any residual error will be known and an adjustment factor can be considered. Bias will be measured by the normalized mean bias (see equation 3 below). A zero bias would define a good baseline. In this phase, the analysis will be done only on D-programmes. In phase 2, the aim is to compare D-programme bias against other baseline types for the FUSION trial.
- Simplicity: This criterion reflects the level of effort and the complexity of implementing and operating/using the baseline methodology, including but not limited to collecting the right data, performing the calculation, and communicating D-programmes to the DSO. This criterion also considers the replicability of the baseline by the aggregator. The main principle of simplicity is that the solution is practical, and the effort required is proportionate to the outcome. Therefore, it will be evaluated using:
  - DSO implementation costs: compare the cost of D-programmes implementation against another baseline methodology e.g., historical; and
  - Aggregator cost of implementation: analyse the extra effort that aggregator needs to put into implementing D-programmes next to their BaU cost.
- Inclusivity: The degree in which the baseline is suitable to use for (almost) all technologies. This criterion will be analysed quantitatively based on the input from aggregators, and the diversity of assets contracted in the FUSION trial.

The aspects on integrity (potential for gaming behaviour) and stackability are left out of the analysis.

To assess quantitative aspects, the baseline variability against the measured meter data will be calculated using the normalized mean absolute error (Equation 2), which is derived from subtracting the measured meter power (m_t) from the baseline value (b_t) to get the error (d_t) at each time step (t) (Equation 1). This approach has been selected as outliers have less of an effect compared with using the variance, therefore, the normalized mean absolute error is more representative of the general spread of errors, allowing outliers to be addressed separately. The bias will be calculated using the normalized mean bias (Equation 3). Finally, the accuracy will be calculated with the relative root mean square error (RRMSE) (Equation 4), which assesses the error after n values.

$$d_t = b_t - m_t \qquad \text{(Equation 1)}$$

$$nmae_p = \frac{\sum_{t \epsilon T} |d_t|}{\sum_{t \epsilon T} m_t} \qquad \text{(Equation 2)}$$

[13] This definition and criteria is based on the report "Baselining the ARENA-AEMO Demand Response RERT Trial" https://arena.gov.au/assets/2019/09/baselining-arena-aemo-demand-response-rert-trial.pdf

$$bias_p = \frac{\sum_{t\epsilon T} d_t}{\sum_{t\epsilon T} m_t} \quad \text{(Equation 3)}$$

$$RRMSE = \frac{\sqrt{\frac{1}{n}\sum_{t\epsilon T} {d_t}^2}}{\frac{1}{n}\sum_{t\epsilon T} m_t} \quad \text{(Equation 4)}$$

The different parameters are calculated on non-event moments and excludes weekends and public holidays.

Whether a historical baseline is more accurate than using a nomination baseline has also been explored. Our method of analysis was to compile the D-programme baselines and meter data for all days between 01/05/22 and 30/06/22. Then, the ENA's baselining tool[14] was used to create a historical baseline using their mid-8 in 10 method, which calculates a rolling average from the middle of the last 8 of 10 days. This new baseline allowed us to calculate and compare the error and bias for the D-programmes and the historical baseline using the normalised mean average error (nmaep), bias (biasp) and relative root mean square error (RRMSE).

Finally, the effect that the baseline accuracy has had on the reliability has been assessed by estimating the probability of delivering at least 100% of the FlexOrder once the accuracy is taken into account. The methodology that followed was to:

- Calculate bias for each aggregator at every congestion point
- Calculate standard deviation of error for each aggregator at every congestion point
- Correct D-programme for bias to calculate the best estimate (i.e. the p50) as per Equation 5
- Calculate the number of standard deviations that the FlexOrder is away from the best estimate (i.e. the z-scores) for each ISP (Equation 6)[15]
- Calculate probability of the delivered power being greater than the FlexOrder power by assuming a normal distribution using the z-score lookup tables

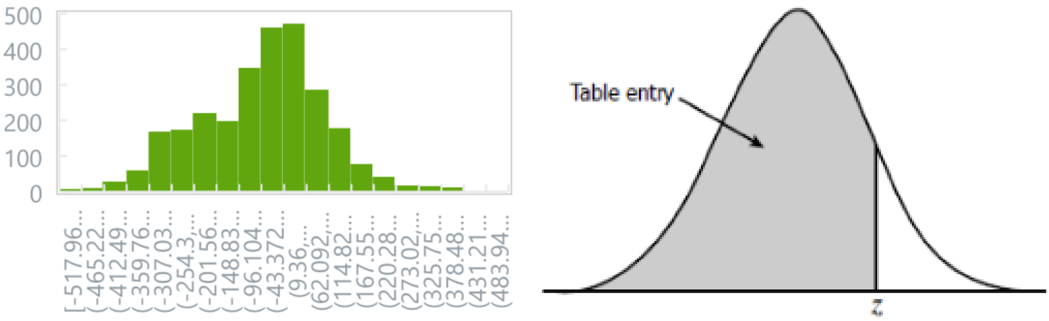


Figure 22 Example distribution of error between D-programme and meter data (for Orange Power at St Andrews) to justify the approximation as a normal distribution to calculate the probability

- Average probability of achieving equal to or greater than the FlexOrder power across Phase 2 of the trial

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[14] ENA Flexibility Baselining 1.0.0 https://ena-baselining.herokuapp.com/baselining_app/

[15] Z-Score: Definition, formula and uses

$$p50 = dprogramme \times (1 - bias_p)$$ Equation 5

$$z = \frac{x - \mu}{\sigma}$$ Equation 6

Where,

x = observed value = FlexOrder power

μ = corrected D-programme accounting for bias = p50

σ = standard deviation of inaccuracy in baseline

4.4.3 Results and Analysis

This analysis has focused on the period between May and June 2022 during Phase 2 of the trial, where aggregators provided sub-meter data for all days in the two months.

4.4.3.1 *Accuracy*

According to our calculations (Figure 21Error! Reference source not found.), Gridimp's RRMSE ranges from –754% to 183% at the two congestion points where they have implemented flexibility. As described in the previous section, an RRMSE value for a good or acceptable baseline should be below 10% or 20% respectively. Therefore, the current values indicate a poor baseline accuracy. To explain this, the individual portfolio characteristics are assessed.

- Gridimp – St. Andrews: The baseline accuracy at St. Andrews was poor (RRMSE of -754%). The portfolio consists of a combination of HVAC and a CHP that is on when the district heating provider is not providing heat to its customer. Gridimp changed their baselining method in Phase 2 of the trial from New England model that is also used in the LEM, to manually inputting what the demand or generation is going to be for large periods of time. A typical example of this is in Figure 24. This method led to significant error as the expected demand was set at a constant value for whole days at a time and only reviewed infrequently. The presence of the 220kW CHP also made it more difficult to forecast as whether the CHP was in an on or off state had a large impact on the total demand. Therefore, the D-programmes was reliant on information about the district heating plans on maintenance or expected behaviour and any unexpected events would affect the baseline accuracy. The baseline showed a strong positive bias meaning that the baseline consistently overestimated what the demand turned out to be.
- Gridimp – Leuchars: the accuracy of the baseline for Leuchars was better than for St. Andrews (RRMSE of 104%). However the reason for this is that the D-programme was consistently set to 0kW and their portfolio consisted of two smaller CHPs that have been operational a low number of hours, therefore, the baseline has been straightforward to predict. Gridimp have plans to also enable residential assets in Leuchars in the next stages of the trial. The baseline showed a strong negative bias meaning that the baseline consistently underestimated what the demand turned out to be.

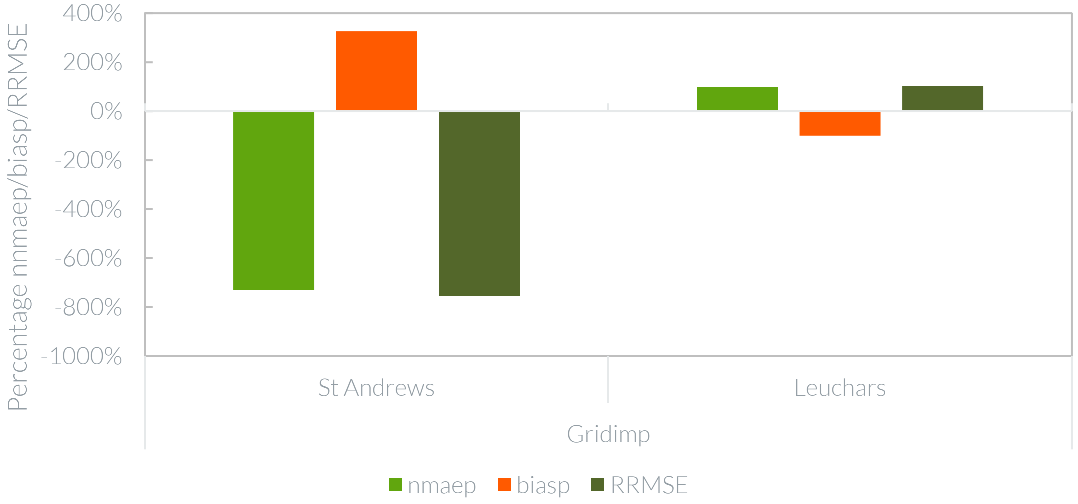

Figure 23 Phase 2 baseline accuracy in May and June 22 for Gridimp

Figure 24 shows Gridimp's baseline at St Andrews for various days in June to represent an example of how Gridimp's constant D-programme affected the accuracy of the baseline.

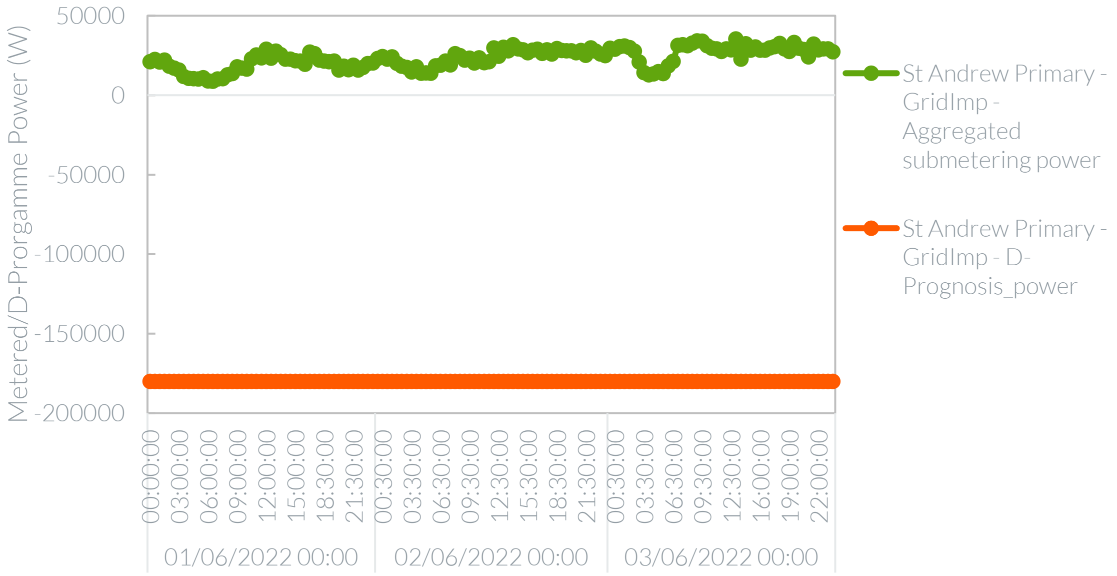

Figure 24 Gridimp – St Andrews D-programme vs sub-meter measurements. Note that generation is denoted as negative power

- Orange Power – St. Andrews: This portfolio is composed of EV chargers, water heaters, and solar PV. Orange Power's forecasting method consists of forecasts per technology supported by machine learning. The RRMSE was 69% which is an improvement on the results from Gridimp but still outside the range of what would be considered acceptable for a baseline. OP struggled initially with data feeding issue and with allocating resources to focus and improve baselines. Rather, they decided to under-promise and overdeliver to avoid the penalty. To assess the accuracy of the forecast, an accuracy factor would have to be applied to correct the bias. Furthermore, OP added new customers which then did not align with the forecasts in the baseline.

- Orange Power – Leuchars: This portfolio includes EV chargers and other residential assets. Orange Power uses the same forecasting method as for the St. Andrews' portfolio. This portfolio forecast is the most accurate out of all of them, at a 63% RRMSE. Orange Power's portfolio at Leuchars consists of a higher proportion of solar PV than at St Andrews which have a more predictable usage pattern for the machine learning algorithm to predict.
- Orange Power – 11kV Feeders: For the feeders, Orange Power decided to use a combination of the machine learning algorithm and manual corrections where appropriate. This additional step was added because of the low number of assets connected to each point, which meant that the behaviour of one or two customers can have a large impact on the demand. Orange Power manually check each forecast created by the machine learning algorithm and if any of the parameters is outside the expected intervals, the D-programme is resubmitted to manually correct them. Despite this additional check the RRMSE for the 11kV feeders was still outside of the range that is considered acceptable (ranging from 103% to 183%). Another contributory factor to the error was that Orange Power had a fault where the same D-programme was received for all three feeders, which has also impacted their results.

Orange Power had a positive bias as each of the congestion point, indicating that they are overestimating what their demand is going to be day-ahead. This means that when the settlement is calculated, the estimated delivered flexibility is likely to be less than the actual flexibility that is delivered.

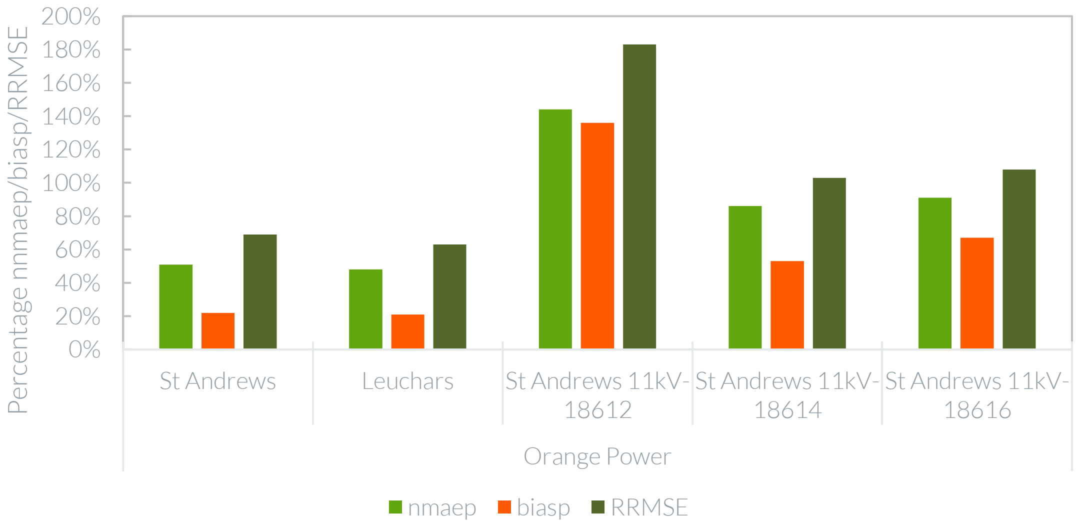

Figure 25 Phase 2 baseline accuracy in May and June for Orange Power

The importance of the baseline accuracy is emphasised when examining the ISP with the largest measured delivery of flexibility in the trial so far (Figure 26). According to the settlement calculations 266kWh of flexibility was delivered based on subtracting the meter power from D-programme. In reality, as shown below, the delivery was a lot less because the baseline was significantly overestimating what the demand would be. By taking the metered demand before the flexible delivery, the reduction in the demand is closer to 110kWh of 40% of what was calculated for settlement. This emphasised the importance of an accurate baseline.

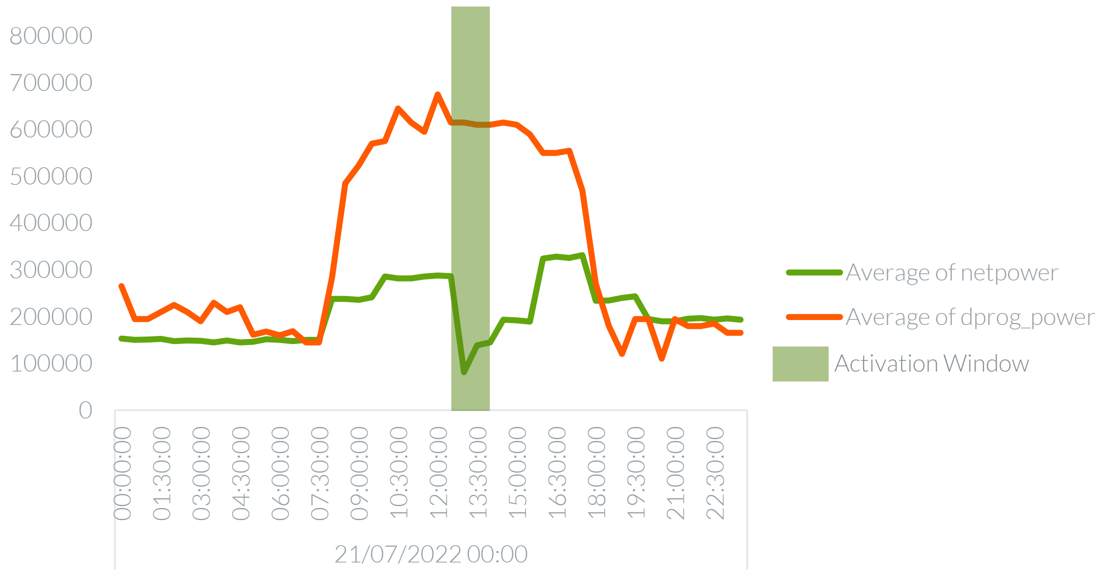

Figure 26 Comparison between D-programme power and meter power for day with highest delivered flexibility. Flexible response is much lower than what will be calculated for settlement due to overestimate of D-programme

The accuracy of the baseline between Phase 1 and 2 of the trial has been compared. Orange Power's baseline accuracy reduced by approximately 5% from Phase 1 to Phase 2 and the other notable change is in the bias at Leuchars which changed from a negative bias (i.e. overestimating the outturn) to a positive bias.

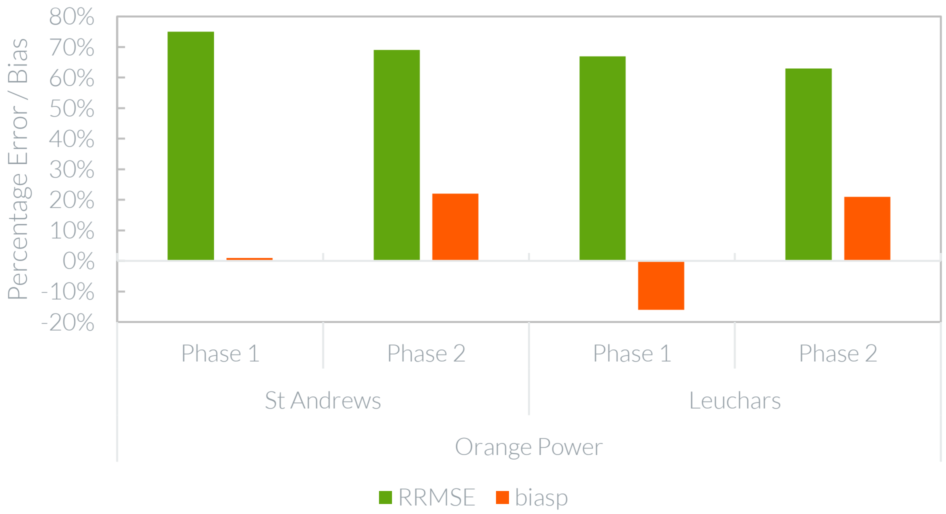

Figure 27 Comparison between Phase 1 and Phase 2 baseline accuracy

Then, the question of whether the D-programmes were more accurate than using a historical baseline methodology was explored. The historical baseline methodology used was the mid-8 in 10 method, which takes the average of the middle 8 of the last 10 days as the baseline. Our results show that for Orange Power, the ENA's historical baseline is more accurate and has less bias than the D-programme at all congestion points (Figure 28). Overall, both methods are not able to achieve baseline accuracies that would be considered good. The accuracy of the baseline is better at St Andrews and Leuchars compared with at the 11kV feeders which suggests that small quantities of flexibility makes it more challenging to reliably predict the behaviour of the assets.

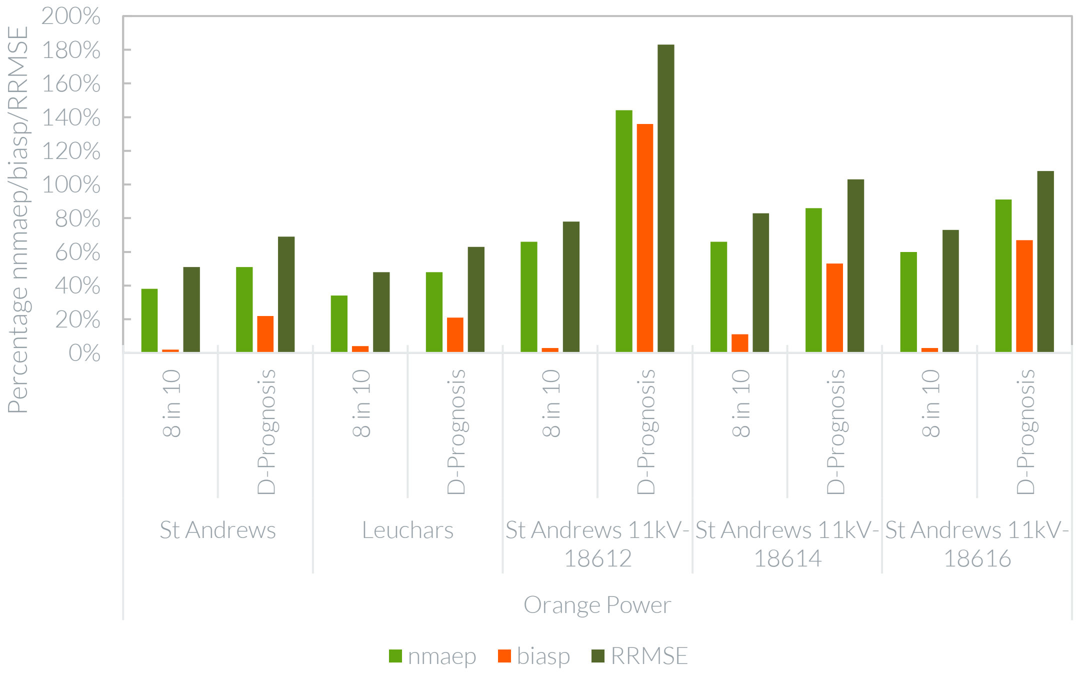

Figure 28 Comparison between accuracy of historical ENA 8 in 10 baseline and D-programme for Orange Power in Phase 2

The results for Gridimp show a similar trend where the ENA historical baseline is more accurate than the nomination baseline. Similarly to Orange Power, all baseline methodologies are not considered good except for the historical baseline at Leuchars, which has an RRMSE of 21%. This accuracy suggests that the behaviour of the two CHPs at Leuchars is easier to predict than at St Andrews where there three separate HVAC assets as well as a CHP.

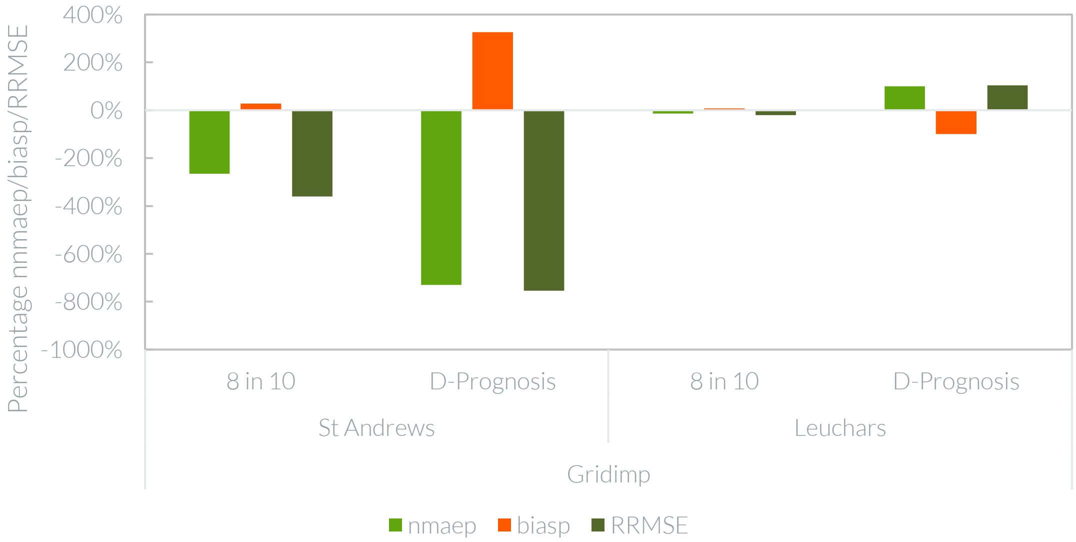

Figure 29 Comparison between accuracy of historical ENA 8 in 10 baseline and D-programme for Gridimp in Phase 2

Finally, we calculated the reliability after taking into account the accuracy of the aggregators D-programme baselines (Table 12). The results are presented in terms of the probability that aggregators achieved at least 100% of the FlexOrder and show a range of probability between 49-65%. These probabilities signify that it is difficult to be sure that the required flexibility has been delivered. The primary reason for this is the large standard deviation in the baseline error, which makes it more difficult to be confident of how much flexibility the aggregator has delivered. These results emphasize the need for an accurate aggregator baseline to guarantee that the procured flexibility is delivering benefit to the network.

Table 12 Reliability of aggregators delivering greater than FlexOrder power after accounting for baseline accuracy

		Reliability of Aggregators Delivering Greater than FlexOrder Power After Accounting for Baseline Accuracy
Gridimp	Leuchars primary	n/a
	St Andrew Primary	64%
Orange Power	Leuchars primary	51%
	St Andrew Primary	49%
	St Andrews 11kV-18612	59%
	St Andrews 11kV-18614	53%
	St Andrews 11kV-18616	52%

Overall, in the Phase 2 interviews, the aggregators and the DSO supported the idea of ongoing monitoring and more regular feedback on the accuracy of the baselines. One option to address this is to add clause in the FSA to include monitoring responsibilities.

Other mechanisms to encourage reliability could also be implemented such as accounting for the accuracy of the baseline in the calculation of reliability or the settlement. In the longer-term, there could be a retrospective reliability metric to select bids based also on their historical performance, carefully considering the weight this could have in the decision process. SP Energy Networks stated that before considering whether to implement these or other mechanisms as a requirement, an enhanced understanding of the baseline would first be necessary.

4.4.3.2 Simplicity

The aggregators indicated in Phase 1 that the implementation of D-programmes required little effort. The level of effort has increased in Phase 2 as the aggregators have trialled alternative approaches to improve the accuracy of their D-Programme including, in the case of Orange Power for the 11kV feeders, adding a manual check to verify and amend the output of the machine learning algorithm.

While this has reduced the simplicity, this shows aggregators capitalising on one of the main strengths of nomination baselines: the ability to adapt and change the methodology based on knowledge of the assets rather than having to follow a prescriptive historical baseline methodology for instance where the baseline is calculated in a completely automated process. Orange Power expressed a preference for D-programmes in their Phase 2 interview.

4.4.3.3 Inclusivity

The aggregators participating in the trial have indicated that they are positive about the use of D-programmes since it allows to baseline the diversity of assets in their portfolios. The aggregators have indicated, however, that intraday submission of D-programmes (after FlexRequest has been sent by the DSO) would be beneficial to improve accuracy.

4.4.4 Conclusions and Learnings

The FUSION trial has successfully used D-programmes (i.e. nomination baselines) for flexibility delivery quantification and settlement.

The accuracy shown by the D-programmes varies per portfolio type. The accuracy of one of the aggregators has improved from Phase 1 into Phase 2 and the other has seen challenges moving into Phase 2. The overall accuracy of the D-programmes is still poor when compared to what literature define as "good" or "acceptable" baseline methodologies. It is worth noting that the portfolios are relatively small, which generally are more difficult to forecast than bigger portfolios.

In Phase 2, aggregators have been capitalising on the opportunity that nomination baselines offer to trial different baseline methodologies to improve the accuracy of their forecasting. Gridimp has trialled inputting a constant baseline to represent the on or off state of their CHPs. This trial has shown that the previous baseline methodology they used, the LEM average, was more accurate, therefore, Gridimp have switched back to using the LEM average. Gridimp plan to improve on the LEM average method by using a same day adjustment (i.e. adjusting the baseline with latest data before submission day-ahead) to better correct to the large changes in the state of CHPs.

Orange Power has tested a baseline methodology based on a machine learning algorithm with manual oversight at the 11kV feeders to account for the smaller flexible capacity that is connected.

Our results show that the ENA's historical baseline method (mid-8 in 10) is more accurate and has less bias than the D-programme at all congestion points. Despite this, the historical baseline is still not able to achieve a baseline accuracy that is considered acceptable at the majority of congestion points. The only exception is Gridimp at Leuchars, where the portfolio consisted of two smaller CHPs that have been operational a low number of hours and have therefore been easier to forecast.

4.4.4.1 Next Steps for this objective

All parties involved recognise the need to monitor the baseline quality as a key first step to improve the baseline. The next steps are therefore to explore alternatives for monitoring responsibilities and potentially add a clause in the FSA. It is also recommended that all aggregators provide daily meter data for all days including non-event moments so that the baseline accuracy can be calculated without the need to request supplementary information.

Gridimp and Orange Power have already implemented or are looking into ways to improve the accuracy of their baselines. Gridimp is currently also exploring introducing a further adjustment to improve the methodology consisting of incorporating an adjustment at 11am DA, to effectively adjust for the large changes in state of CHPs. Using D-programmes enables testing this type of adjustment as it allows to incorporate the understanding of the assets to adjust the baseline accordingly. Orange Power is using a black box methodology for the baseline, so a solution would be to hire a machine learning data engineer to make improvements on the algorithm. Orange Power will resolve the issue with the D-programmes of the feeders and will provide a separate differentiated prognosis for each of the feeders.

Further, Project FUSION will explore the accuracies achieved with other baselines methodologies, such as meter before meter after (MBMA) and historical baseline combined with same day adjustment (SDA). Next to the accuracy, other aspects such as gaming will be addressed.

4.5. MARKET COORDINATION MECHANISM (MCM)

4.5.1 Scope

During FUSION trial phases 1 & 2, flexibility trading was done according to the USEF market coordination mechanism (MCM). The USEF MCM facilitates flexibility trading and consists of five phases – contract, plan, validate, operate and settle. During the trial, the contract phase was done at the procurement stage whereas the phases from plan to operate were conducted day-ahead and intraday. Finally, the settle phase was done once per month.

The different services and test cases have been trialled according to the MCM during phases 1 & 2. The scope of this objective is to evaluate the experience of the difference parties using this mechanism as well as the fit to the different services.

4.5.2 Methodology

This objective is evaluated in a qualitative and quantitative manner. The qualitative element was covered through interviews and questionnaires that DNV conducted with aggregators and SP Energy Networks. The qualitative analysis covers:

- Experience of aggregators and DSO using the MCM
- What is the FlexReservationUpdate value to the AGR (by bringing flexibility to other markets)?
- Partial FlexOrders
- Rebound considerations

The quantitative analysis covers:

- MCM impact on reliability
- MCM impact on efficiency linked to DSO forecast accuracy

4.5.3 Results and Analysis

Experience using MCM

Aggregators consider the MCM useful, clear and well structured, as they benefit from the whole process being defined in a single system. This integrated approach avoids having to switch between different platforms when bidding, operation and settlement. Improvements have been identified on the timing of the contract phase and in the bid selection process.

Contract phase timing

Aggregators highlighted certain issues linked to the timing in which the contract phase of MCM was taking place for Project FUSION. This timing was chosen by the project and it is not linked to any prescriptions of USEF. The contract phase of phase 2 of the trial included a full year of contracted availability. Gridimp mentioned that committing availability so long in advance was very difficult with their type of assets. Gridimp's portfolio mostly consists of back-up CHPs that are activated when the district heating fails (which is fairly often), creating challenges for Gridimp to commit availability months/years ahead. In addition, Gridimp did not have sufficient data of the asset performance just after contracting with their customers, the real flexible capacity is known after having operated the flexible asset for some time. Therefore, Gridimp suggested to shift the contractual phase on availability closer to real time, e.g. one week ahead. This will reduce aggregator's risk (penalties, redundant flexible capacity, etc.) by reallocating some of these risks to the DSO (shorter term planning).

Although free bidding would serve partly as a solution for this issue, the DSO is not willing to only rely on free bids yet. Plus, aggregators still need to rely on availability payments for their business case to be feasible.

Bid selection

At the moment, SP Energy Networks selects bids (i.e. sends FlexOrders) based only on the FlexOffer price. SP Energy Networks suggested exploring the addition of the GHG emission element to the selection of the bids to be utilised, either with historical performance metric of the aggregators or by a metric established at the contractual phase assessing the carbon footprint to the portfolios compared with the competitors.

Partial FlexOrders

Phase 2 had the ambition to trial partial FlexOrders, however, this was not possible due to FFP limitations in the UFTP implementation. Aggregators proved to be capable to submit partial FlexOffers. The DSO would find this feature particularly useful in their operation of the FFP, in situations in which the need for flexibility intraday is lower than the requested amount day ahead.

FlexReservationUpdates

FlexReservationUpdates is a USEF concept that allows the DSO to release the aggregator from their availability contractual obligations when flexibility is not needed. In the FUSION trial phase 2, FlexReservationUpdates were sent day-ahead to aggregators in test cases 1.3, 2.5 and 3.3.

Aggregators believe that FlexReservationUpdates bring significant value to them, since it would allow them:

- To avoid sending a false alarm to customers if they are not going to be activated (alarm is sent when the aggregator sends a FlexOffer to the DSO)
- To manage their portfolio and make assets available for other uses. During phase 2, aggregators did not use this feature and offered their flexibility in other markets, simply because they are not active in other markets yet. Nonetheless, in the future, they consider offering flexibility for e.g., to the new ESO DFS service and the BaU DSO flexibility services of Scottish Power.
- Potentially adjust their bidding strategy. If there is value stacking with flexibility reserves, this may allow aggregators to adjust the bids to make them more competitive for the DSO.

Rebound considerations

Phase 2 had the ambition to incorporate the rebound effect into the flexibility procurement. The MCM allows for the aggregators to provide rebound forecast attached to their FlexOffers. However, this was not possible because aggregators did not have the capability to forecast the rebound effect of their offers.

The aggregators did provide some qualitative information on rebound:

- Gridimp indicated that there is a rebound expected from HVAC assets in the following two hours after activation.
- There is no rebound expected from CHPs.

Since the project could not generate quantitative data on rebound effect due to inaccuracy of the baseline, the next interim learnings report will include an analysis of the rebound based on assets participating in the trial, aggregator insights and literature.

MCM impact on reliability

In theory, the MCM could have a positive impact on reliability because:

- It allows portfolio bids which would enable more flexibility to aggregators to choose assets that are available in the moment of delivery as well as the diversification of assets to provide a service.

- It allows shorter timeframes for flexibility trading which allows representation of the close to real time status of the flexible assets.

The full analysis on reliability during the FUSION trial can be found in Section 3.3. The overall reliability across all congestion points was 73% (excluding Gridimp in St. Andrews as an outlier). When focusing only on Orange Power the accuracy is 86%.

Since there is not enough data on BaU DSO flexibility services, the reliability assessment needed to be performed against other trial results.

Reliability results in other flexibility trials

- BaU – Energy Networks, ENWL, UKPN, SSE and Western Power were consulted. Small volumes have been traded, with currently no data available.
- Other available trial data (Table 13) – the reliability values found are 58-72%, averaging 65%. These values are not fully comparable. For further assessment, the key partners of these main projects could be further consulted.

Table 13 Flexibility reliability in DSO services obtained in GB innovation projects

Project	Key partners	Calculation method	Final value	Main References
TRANSITION & LEO project (2022)	Origami (now Baringa), SSEN, Electricity North West	Reliability index = supply delivered/ supply purchased	Weighted average is 72%.	Transition & project LEO – Market Trials Report (Period 1)
Cornwall LEM (2019) Phase 1 = The Visibility Plugs and Socket (VPaS) project (May-Aug 2019) Phase 1 and 2 (May-Dec 2019)	Imperial College London, WPD, Centrica	Delivery proportion = service delivered (MWh)/service procured (MWh)	Phase 1 – on average, 60% of the expected MWh were delivered. Phases 1 and 2 average = 58.3%	Cornwall LEM Flexibility Market Platform LEM Flexibility Market Platform Design and Trials Report Cornwall LEM report repository
ENTIRE (2019)	WPD	Service reliability is acceptable if dips in requested output are not below 95%.	22% of events were continuously above 95%, 41% were above 63%.	Visibility Plugs and Socket – Phase 1 interim learning report ENTIRE – operational trials report

	ENTIRE Project Website

Comparison

The flexibility delivery under FUSION trial is between 1% and 28% more reliable than the one calculated under other DSO flexibility trials.

This reliability increase will be included in the FUSION Cost Benefit Analysis to be published Q1 2023.

Project partners acknowledge that the reliabilities in the different trials are not fully comparable, however this is the only data available to perform such calculation.

Hence, we recommend to DSOs to register and publish this data for the wider benefit to industry.

MCM impact on efficiency linked to DSO forecast accuracy

Background and hypothesis

In theory, the MCM could have a positive impact on efficiency because:

- It enables shorter timeframes for the DSO to have a more accurate view on the grid needs and presumably a lower forecasting error.
- The DSO would need to procure less flexibility to account for potential forecasting errors

This analysis looks into the load forecast accuracy for longer timeframes (up to 4 days ahead) which aligns with the common DSO BaU operations, and shorter-term forecasts (day-ahead, and intraday) that characterises the USEF MCM. The difference in accuracy would determine the potential impact that USEF could have on flexibility procurement efficiency.

Quantification

The load forecast is used by the DSO to determine the required volume of flexibility. In practice, the load forecast includes a certain inaccuracy. This inaccuracy leads to a bandwidth in the forecast. To mitigate the impact of an inaccurate forecast, flex procurement needs to be based on the upper bound of the load forecast to account for this inaccuracy. This could lead to a higher flexibility procurement than necessary. This analysis covers the load forecast inaccuracy for 5 congestion points: Leuchars, St Andrews, feeder 18612, feeder 18614 and feeder 18616.

The questions answered in this analysis are:

- How does the accuracy of the forecast vary in the days before the event and what does that tell us about when flexibility should be procured?
- How does the inaccuracy of the forecast influence the DSO procurement strategy?

This exercise is performed for the service window 10:00 – 18:00 because the peak of the day generally falls within this period, see Figure 30 below. The analysed period is that of October 2021 towards June 2022. Two datasets are analysed: Actual metering data of the congestion points and the forecasted load.

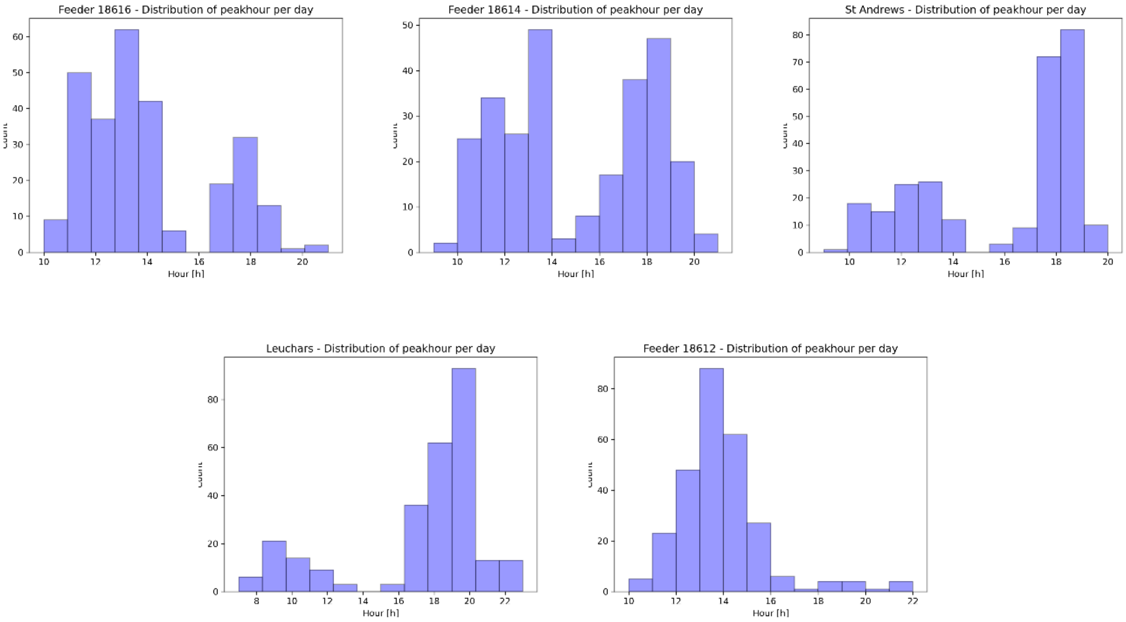

Figure 30 Distribution of peak hour per congestion point

The forecast of mid-day (12:00) is taken, in order to have one forecast datapoint per day. Then the difference between the forecast and the actual metering data is calculated per *forecast day* [Δ = Actual - Forecast]. Forecast day is here defined as 4, 3, 2, 1 days before and intra-day. This results in a load difference between the forecasted load and the metering data per day. Then the difference is divided by the Forecast [λ = Δ / Forecast], in order to get the inaccuracy in a percentage (represented by symbol λ).

This exercise is repeated for all metering datapoints, which is about 5000 per congestion point. The inaccuracy is then plotted in a distribution graph in order to show the median and the spread of the inaccuracy.

When the inaccuracy percentage is positive, the forecast is lower than the actual, thus more flexibility should be procured than forecasted.

Flex procurement can include the load forecast inaccuracy in order to mitigate the impact of an inaccurate forecast. Flex procurement on day *i* would be as follows:

$$\text{Flex procurement}_{\text{day } i} = \text{Forecast}(1+ \lambda_{\text{day } i}) - \text{Rating}$$

All results are included in the Table 14 below. For one congestion point (Leuchars) the distribution plots of the load forecast inaccuracy are included in Figure 32. In the graphs, the median and the standard deviation is given. In this case, the median is negative for each day, indicating a slight overall overestimation of the forecast. That would mean that currently, flex procurement is also slightly overestimated. As the distribution curve is normally distributed, we can assume a 68% confidence as one standard deviation and 95% confidence as two standard deviations. 68% confidence interval means that 68 samples of the datapoints lie inside the upper and lower bounds of the standard deviation.

For example, for the intraday forecast the median inaccuracy is -0.56% and one standard deviation is 11.02% (inaccuracy of 10.46%). A less risk-based approach would be taking two standard deviations (95% confidence) and leads to an inaccuracy of 21.48%.

Table 14 Load forecast inaccuracy results per congestion point, columns are median (M), 68% confidence and 95% confidence

Congestion point	Load Forecast Inaccuracy														
Days before	Intra-day			1			2			3			4		
	M	68%	95%	M	68%	95%	M	68%	95%	M	68%	95%	M	68%	95%
Leuchars	-0.6	10.46	21.48	-0.8	10.51	21.81	-0.9	10.65	22.23	-0.7	11.25	23.9	-1.2	11.29	23.82
St Andrews	-0.3	6.79	13.83	-0.4	6.87	14.11	-0.2	7.39	14.94	0	7.89	15.74	0.03	8.36	16.69
St Andrews 11kV-18612	-0.9	13.88	28.68	-1	14.16	29.31	-0.6	14.75	30.13	-0.5	15.3	31.1	-0.6	14.45	29.49
St Andrews 11kV-18614	-3.6	121.7	246.9	-3.8	122	247.7	-4.3	122.4	249	-4.3	122.8	249.9	-4.5	123.1	250.6
St Andrews 11kV-18616	-1.6	10.04	21.71	-1.9	10.11	22.12	-1.6	10.35	22.33	-1.5	10.57	22.64	-1.2	10.74	22.7

The results indicate that the accuracy and the confidence of the forecast is generally better for shorter timeframes than longer timeframes. However, this difference is not relatively small ranging from 1 to 3% improvement in intraday timeframes.

How would this affect the DSO procurement?

The DSO would account for the risk of any potential forecast errors when procuring flexibility. The results tell us that procuring flexibility within a shorter timeframe following the USEF MCM, the DSO would need to procure 1-3% less flexibility compared to longer procurement timelines (3-4 days ahead).

The effect of the forecast accuracy in the overall DSO procurement strategy is further developed in Section 4.7.

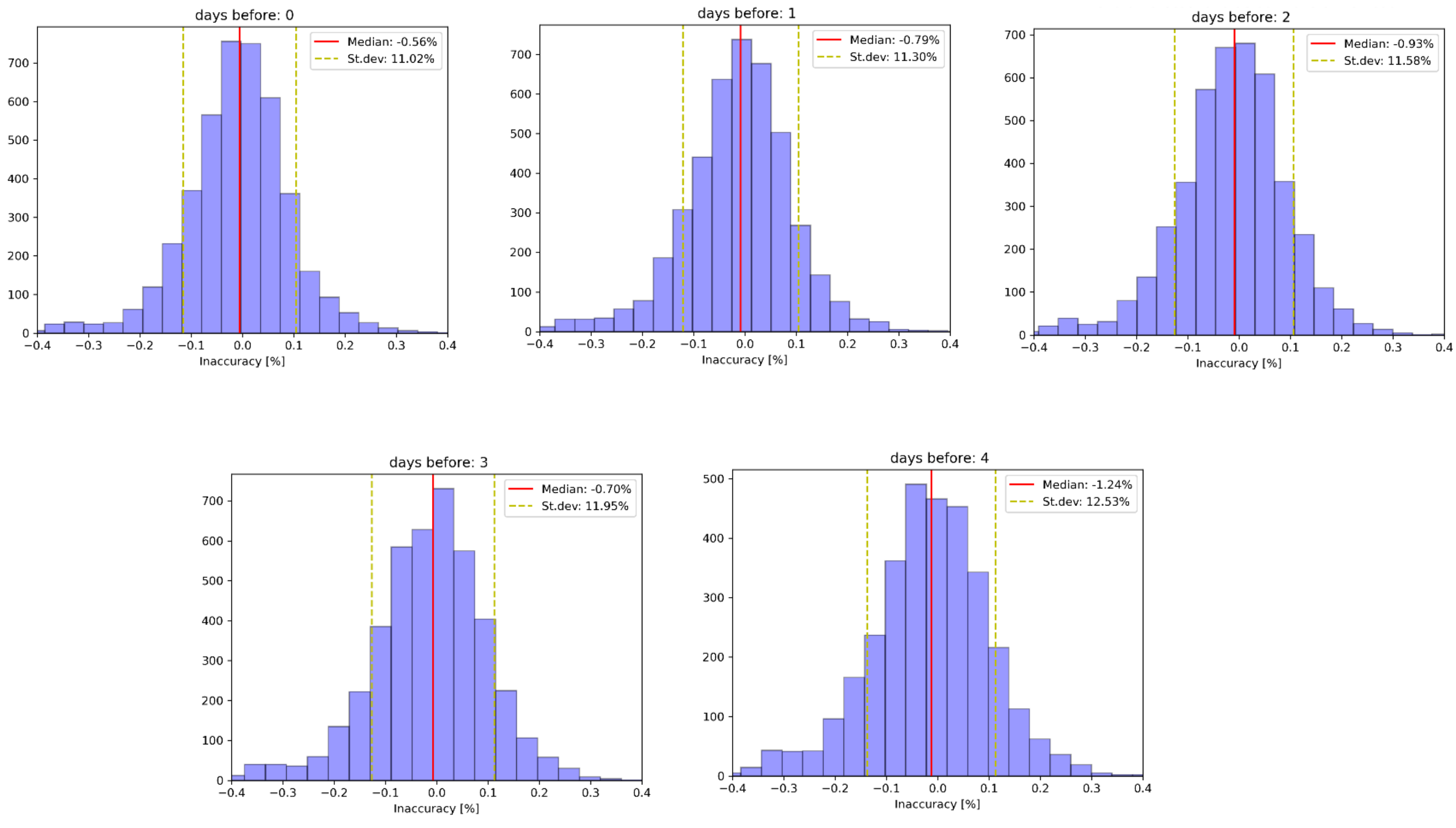

Figure 31 Distribution figures of load forecast inaccuracy of congestion point Leuchars

4.5.4 Conclusions and Learnings

- Aggregators consider the MCM useful, clear and well structured, as they benefit from the whole process being defined in a single system, avoiding the need to use several systems across different phases.
- Aggregators and DSO made suggestions for improvement on contract timing aspects (week-ahead availability contracts) and bid selection (inclusion of carbon emissions information).
- MCM has a positive impact on reliability - between 1-28% increase - compared to other DSO flexibility trials.
- MCM has a positive impact on efficiency linked to DSO forecast accuracy. Because of its shorter procurement and dispatch timeframes, USEF allows a 1-3% reduction of DSO flexibility needs to account for forecast inaccuracy for the locations studied.

4.5.4.1 Next steps for this objective

- Incorporating the remaining trial data to this analysis.
- Reporting theoretical rebound effect associated to the FUSION trial.

4.6. USEF FLEXIBILITY TRADING PROTOCOL (UFTP)

4.6.1 Scope

In the FUSION trial, the interaction between SP Energy Networks (DSO) and the aggregators has been formalised the USEF Flexibility Trading Protocol (UFTP), now known as SHAPESHIFTER.[16] The USEF Flexibility Trading Protocol (UFTP), describes the interactions and communication exchange between aggregators and DSOs to resolve grid constraints at distribution level. The UFTP covers all phases in the USEF Market Coordination Mechanism (contract, plan, validate, operate and settle) and is designed to be used as a stand-alone protocol for flexibility forecasting, offering, ordering and settlement processes. More details on the implementation of UFTP and its technical requirements are provided in **FUSION's Interim Trial Learnings Report #1** which was published in October 2021. Further analysis can be found in **FUSION's Interim Trial Learnings Report #2** published in May 2022, this section building on this previous assessment.

4.6.2 Methodology

This objective builds on the analysis carried out in the **ITLR#2** report. The assessment method of the UFTP objective was qualitative. To obtain the required information, DNV engaged with SP Energy Networks, OpusOne and aggregators through bilateral discussions and an interview process. The qualitative assessment aimed to cover:

- Experience using UFTP
- Advantages of UFTP
- Areas for improvement
- Feedback to improve the protocol
- Changes to the protocol

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[16] https://www.lfenergy.org/projects/shapeshifter/

4.6.3 Results and Analysis

Experience using UFTP: Both aggregators consider the UFTP has worked smoothly throughout the phases of the trial, with communication being timely and straight forward. Aggregators shared that implementing the protocol encouraged them to also assess and improve their own processes.

There is also awareness of the fact that the UFTP is perceived as complex. However, aggregators suggest that UFTP has a similar level of complexity as other standards that automate the process end-to-end. This implies that UFTP should not be compared with other protocols that only cover simpler processes, such as dispatch and metering, and do not include market interaction.

SP Energy Networks has also indicated that they have not experienced any issues using the protocol throughout Phase 2. They highlighted that in the future it would be beneficial to automate the process to send FlexRequests. This is something that UFTP enables and could be implemented in the FFP.

Advantages of UFTP: All advantages were already identified in ITLR#2 report

Areas for improvement:

Settlement process

SP Energy Networks and Gridimp acknowledge a more automated settlement process would be beneficial, nonetheless, challenging due to the high number to features that are to be considered. At present, UFTP only covers the utilisation payment linked to FlexOrders but it does not cover availability payments or accounts for the aggregator performance. Hence, they suggest adding availability payments to the protocol.

Hierarchy of congestion points

In ITLR#2 report, OpusOne (FFP provider) highlighted that UFTP was not fit-for-purpose for GB market. The main reason for this was the lack of hierarchical representation of congestion points in the network.

UFTP provides the data schema to relate a flexibility portfolio to a congestion point on the network. Because UFTP, by design, does not store any other information regarding the grid topology, such as a hierarchical representation of the network, this could impact the level of powerflow interaction possible between voltage levels, which is a regular occurrence on distribution networks. For example, the implementation of 11kV feeders under 33kV substations proved challenging to implement given that UFTP does not have a native mapping of congestion points. Hence, the FFP could not map a connection to both voltage levels. As a protocol, UFTP also does not support more granular network-model based analysis such as CIM network models.

USEF/ UFTP assumes the DSO to develop and manage their own system to have visibility on flexibility needs and impact within different voltage levels, whereas UFTP covers the flexibility trading processes and communication with aggregators. The multiple voltage issue limitations encountered in FUSION are caused by the single connection-congestion point relationship modelled in UFTP.

Feedback to improve the protocol

Project FUSION has continuous engagement with the Technical Steering Committee (TSC) of SHAPESHIFTER (under LF Energy) to provide feedback on issues that the project encounters.

Currently, the Project FUSION is in the process of submitting a change request to remove a barrier on the hierarchy of congestion points issue raised by OpusOne. The project is going to propose to change the single connection-congestion point relation and allow for connections to be linked to multiple congestion points.

During discussions with SHAPESHIFTER TSC, it was highlighted that the aim of the protocol is not to provide the DSO with a network model but with a flexibility trading process. Moreover, incorporating a hierarchical link between congestion points would be extremely challenging given the variety of network configurations, such as mazed grids. Therefore, it was reconfirmed that the DSO would be responsible for understanding the relation between congestion points and the effect of flexibility at different voltage levels outside the common register.

Contributions of Project FUSION to the protocol

The ITLR#2 report described the changes requests that were submitted to the SHAPESHIFTER TSC on 1) metering and 2) service type. Version 3 of UFTP/SHAPESHIFTER[17] has now added:

- Metering message: This message is exchanged during the Settle phase for the aggregator to send meter data to the DSO. This was added to enable metering exchange in the absence of meter data from the meter data company (MDC) which would normally be at MPAN/main meter level. This message enables the exchange of submeter data directly between aggregator and DSO.
- Service type attribute in FlexRequest message: This attribute enables the DSO to add the service type that they need (e.g. dynamic, sustain, secure) in their FlexRequest. This change will make the protocol align better with the current DSO product design in GB.

4.6.4 Conclusions and Learnings

The conclusions of the assessment of the UFTP objectives are:

- Aggregators and SP Energy Networks found the experience with UFTP smooth and positive. Aggregators perceive that the complexity of the protocol is on par with other protocols that cover similar processes.
- Improvements regarding settlement and congestion point hierarchy were identified by DSO, aggregators and FFP provider.
- FUSION Project is interacting with SHAPESHIFTER TSC to discuss potential improvements to the UFTP protocol and is in the process of submitting a change request regarding congestion point hierarchy.
- Previous change requests and feedback given by Project FUSION has already been implemented in version 3 of the protocol.

4.6.4.1 Next steps for this objective

- Submission of change request regarding congestion point hierarchy
- Continue to feedback learnings to SHAPESHIFTER TSC

4.7. DSO FLEXIBILITY PROCUREMENT COST DRIVERS

4.7.1 Scope

FUSION seeks to demonstrate whether the use of USEF innovative elements will lower the overall costs of flex procurement. This can be accomplished in two ways (apart from CAPEX and OPEX costs for the DNO):

- Lowering the price of flexibility (attracting more flexibility, remove barriers, lower investment costs)
- Lowering the required volume (either availability, utilisation or both)

[17] https://github.com/shapeshifter

This section provides insights on the second element, by discussing several of the main cost drivers for flexibility procurement, focusing on the utilisation costs (utilisation volumes). The aspects that have been considered are:

- Load forecast accuracy
- Baseline accuracy
- Service delivery reliability

The load forecast is used by the DSO to determine the required volume of flexibility. Load forecasts include a certain inaccuracy. This inaccuracy leads to an upper and lower bound of the load forecast resulting in more flex procurement than is required.

A baseline approximates the energy consumption or generation by an aggregator if no flexibility is activated. It is used to determine the required volume of flexibility (both availability and utilisation). In practice, baseline methodologies include a certain inaccuracy. This inaccuracy leads to a bandwidth for service delivery and can lead to two scenarios

- The DSO carries the risk by factoring in the inaccuracy when it procures flexibility by procuring more than required
- Aggregators carry the risk and factor it in by overdelivering of what was ordered

In both scenarios, the cost of flexibility is likely to increase. Either because the DSO regularly procures more flexibility than required or because the aggregator increases the price per kW that they contract as available to ensure they have enough assets. In reality, the risk from the inaccuracy of the baseline is likely to affect both parties.

The final driver is that the service delivery by aggregators is not fully reliable. The DSO mitigates against this by either contracting with multiple aggregators or by over-procuring flexibility at additional cost. A service contract can include a minimum service level on performance and reliability; however it is worth noting that the higher the reliability requested by the DSO, the higher the unit price of the service.

In this section, we firstly describe the additional flexibility required after accounting for FUSION's Phase 2 trial results for the forecast accuracy, baseline accuracy and reliability These results are then compared with an approximation of the additional flexibility that would have been required in a hypothetical business-as-usual case that assumes typical values for the three different cost drivers.

4.7.2 Methodology

Using the results from Phase 2 of the FUSION trial, we have examined all cost drivers together to understand their combined impact on the additional flexibility required (Error! Reference source not found.).

The additional flexibility required due to the baseline accuracy is based on the normalised mean average error and assumes that an even share of the risk is divided between the aggregator and the DSO. It is worth noting that this extra flexibility only accounts for the average error in the baseline therefore the value would be higher if the DSO wanted to ensure to a greater confidence that the flexibility procured was sufficient to meet the system need.

The column related to the additional flex required due to DSO load forecast accuracy shows the inaccuracy per congestion point for the one day before forecast with a 95% confidence level.

Finally, the additional flexibility required due to reliability delivery is based on the Phase 2 reliability figures (Figure 8).

To calculate the combined additional flexibility required due to all factors, the impact from each driver was compounded to give an overall additional percentage.

Next, we calculated the same table but using equivalent values for the forecast accuracy, baseline accuracy and reliability in a hypothetical business-as-usual case (Error! Reference source not found.). The purpose of this was to estimate whether more flexibility would have been required for a trial setup that was more akin to current BaU flexibility procurement processes. In those, the flexibility is procured further in advance of delivery, using a historical baseline methodology and, as observed in Section 4.5, achieves a lower reliability.

For BaU, we used the DSO load forecast inaccuracy per congestion point four day ahead forecast with a 95% confidence level. To reflect the accuracy of a historical baseline, the results from the normalized mean average error for the ENA's mid-8 in 10 baseline method were used (from Section 4.4.3). Finally, as discussed in Section 4.5.3, flexibility delivery under FUSION trial is between 1% and 28% more reliable than the one calculated under other DSO flexibility trials. We have therefore used the midpoint of this range to estimate how this affects the additional flexibility required.

The final step was to calculate the difference between the trial results and the hypothetical BaU case by subtracting the trial results for all factors combined from the business-as-usual comparison (i.e. a positive value (coloured in green) reflects that more additional flexibility is required in BaU than in FUSION).

4.7.3 Results and Analysis

Additional Flexibility Required Based on FUSION Trial Results

The results show that significant additional flexibility would be required across all congestion points to account for the different drivers: ranging from 65% to 1390% (Table 15).

Table 15 Additional flexibility required due to different cost drivers based on FUSION Phase 2 trial results

Aggregator	Congestion Point	Additional Flex Required due to DSO Load Forecast Accuracy	Additional Flex Required due to Baseline Accuracy	Additional Flex Required due to Reliability of Delivery	Combined Additional Flex Required due to all Factors
Gridimp	Leuchars	22%	50%	27%	132%
	St Andrews	14%	365%	181%	1390%
Orange Power	Leuchars	22%	24%	15%	74%
	St Andrews	14%	26%	15%	65%
	St Andrews 11kV-18612	29%	72%	15%	155%
	St Andrews 11kV-18614	248%	43%	13%	462%
	St Andrews 11kV-18616	22%	46%	8%	92%

The impact of the load forecast accuracy varies significantly across the different congestion points. DSO can procure closer to real-time or improve the forecasting methodologies. FUSION assessed the forecast accuracy in different time frames (Section 4.5.3) and found that there was only several percentage points difference between the 95% confidence interval for intraday and four days ahead therefore there is not a significant benefit when ordering closer to real time. We have also tested both day ahead and intraday trading of flexibility (Figure 14). The results showed that intraday FlexOrders were less reliable than day-ahead, therefore ordering more flexibility day-ahead would have reduced the additional flexibility required.

The baseline accuracy had the largest impact on the additional flexibility required. The options that are typically available to a DSO to improve the accuracy are to allow different baselining methodologies or to allow sub-metering of assets. FUSION tested a nomination baseline and sub-metering which allows aggregators to choose the precise methodology and adapt it as they see fit. Both aggregators are implementing changes to attempt to improve the accuracy of their baseline therefore, this will be reviewed again in the next interim learning report. The aggregators also requested more regular feedback on the performance of their baseline to enable to adapt their methodologies moving forward and take advantage of the flexibility in approach that USEF provides.

Finally, the service reliability had the least impact on the additional flexibility required. Increase service level (i.e. raise penalties for under-delivery). FUSION monitors service reliability to provide greater insights to DSOs as to the reliability of aggregators in delivering flexibility.

Business-as-Usual Case Comparison

The results show that the business-as-usual case requires more flexibility in four out of the seven congestion points. For the three instances where the trial requires more flexibility, the reason for this is the much-improved accuracy of the ENA's 8 in 10 method compared with the accuracy observed in the D-programme. This emphasizes the need to focus on aggregator baselines as the trial progresses.

Table 16 Additional flexibility required assuming business-as-usual values for load forecast and baseline accuracy and reliability

Aggregator	Congestion Point	Additional Flex due to DSO Load Forecast Accuracy	Additional Flex due to Baseline Accuracy	Additional Flex due to Reliability of Delivery	Combined Additional Flex due to all Factors	Delta Between Additional Flex in FUSION and BaU[1]
Gridimp	Leuchars	24%	7%	42%	88%	-44%
	St Andrews	17%	133%	196%	704%	-686%
Orange Power	Leuchars	24%	17%	30%	88%	14%
	St Andrews	17%	19%	30%	80%	15%
	St Andrews 11kV-18612	29%	33%	30%	122%	-33%
	St Andrews 11kV-18614	251%	33%	28%	495%	33%
	St Andrews 11kV-18616	23%	30%	23%	96%	4%

[1] A positive value (coloured in bright green) shows that more additional flexibility is required in BaU than in FUSION

4.7.4 Conclusions and Learnings

The trial results that the different cost drivers would have a significant impact on the volume of flexibility required by the DSO to ensure that the required flexibility is delivered. In particular the baseline accuracy has a large impact, for the FUSION trial as well as BaU, and therefore is an area that requires attention as the trial moves into the next stages.

An even split in the risk of reliability of delivery (and baselining implications) between the DSO and aggregators was assumed, however it is important to have a better understanding on how to split the risks between DSO and aggregator. Besides, it is key to understand how different measures would impact both the DSO and aggregators, for example if a certain level of baseline accuracy was required, some flexible technologies might be excluded, leaving more expensive technologies which would come at a higher cost for the DSO. The following questions will be explored in the next stages of the trial:

- How does the risk distribution affect the flexibility cost?
- How can it be achieved without hampering the entry of flexibility into the market?
- How does it affect the decision process of the DSO?
- Should reliability and baseline quality be included in the tendering process? How would that affect the aggregator and the DSO?
- How would the inclusion of other baseline methodologies, e.g. historical with same-day-adjustment, would affect the DSO?

The comparison between the trial results and a hypothetical business-as-usual case has shown that the FUSION trial requires less additional flexibility at four of the seven congestion points. This shows that the USEF framework can reduce uncertainty in the drivers that affect flexibility procurement costs and therefore reduce DSO costs compared with BaU flexibility markets.

It is also worth noting that conclusions about reliability cannot be drawn without accounting for the baseline quality. These two drivers are therefore interlinked, and both have to be addressed to give confidence that flexibility delivery will be solve grid congestion when it is ordered.

4.8. COMMERICAL MECHANISMS

4.8.1 Scope

One of the aims of Project FUSION is to explore the commercial mechanisms available to encourage consumer participation in providing flexibility, with a particular focus on how well USEF facilitates these mechanisms. Currently in the market, there is a clear dominance of larger market players. Project FUSION assesses how effectively commercial mechanisms support providers with lower levels of flexibility and explore how the project could be used to inform the development of such mechanisms.

This sections firstly outlines the methodology for how the trial will be assessed to gain insights into commercial mechanism, discuss the updated findings from Phase 2 of the trial and reflect on the key learning and conclusions.

4.8.2 Methodology

This section will assess the effectiveness of commercial mechanisms in encouraging flexibility from providers (particularly providers with lower levels of flexibility). It initially provides an overview of the context and different routes to market available, discusses the barriers and opportunities for encouraging customer participation, the market procurement timelines and then focuses on free bids as a mechanism within USEF that has the potential to encourage wider participation.

To inform the above objective, feedback has been collected using a variety of means, including a series of questionnaires and interview sessions with each of the aggregators participating in the FUSION trials and summarised in this report.

4.8.3 Results and Analysis

4.8.3.1 Context and Routes to Market

As a reminder from ITLR2, aggregators advised that there are ample routes to market for new flexible assets. Aggregators identified three key routes, which have been used by asset owners to date:

1. Business-to-business

Usually a discussion between the aggregator directly with a potential business customer.

2. Domestic (business-to-business)

Typically conversations with hardware companies that represent multiple residential customers.

3. Direct to customers

Usually one of the following routes; advertising opportunities for participation on the aggregator website, transferring existing DSO customers onto platform or via a social media campaign.

USEF proposes standardisation of the interaction between aggregator and flexibility provider platforms and flexibility services. Therefore, even though there are multiple different routes to market, USEF enables onboarding to be streamlined through standardisation and a lower entry cost.

4.8.3.2 Barriers and Opportunities

Aggregators discussed various barriers to the recruitment of additional flexible assets in their end of phase interviews. One of the aggregators discussed their challenges within Phase 2 of the trial in recruiting additional flexible assets from business customers. The need for additional assets came about in response to the unavailability of assets that had already been signed up to the trial, which meant that they required additional flexibility to reach their contracted availability volume. They noted the technical challenges in getting assets connected and enabled and the difficulties in communicating with businesses that work with multiple subcontractors. These challenges increased the lead time for the connection of new assets.

Aggregators also saw the financial incentives in the trial as a potential barrier to encouraging participation. They advised that a structure and balance of payments between utilisation and availability that rewards delivery would make it easier to recruit new assets. One options for achieving is to increase the utilisation payments in relation to availability. It was felt that this would reward and encourage domestic customers who have a lower flexible capacity but could earn comparatively more through utilisation.

The customer operational considerations were also seen as affecting their likelihood to participate. A lack of standardisation of meter data across different assets makes onboarding new assets and settlement challenging. Aggregators suggested that this could be standardised in the ESA with a uniform API for uploading it.

Aggregators also advised that day ahead notification provides customers with more visibility of when their assets will be utilised and can therefore adapt accordingly. This type of notification is therefore easier to sell to potential customers than shorter notification times between FlexOrders and delivery. This emphasises the importance of increasing the incentive for delivery when notification times are shorter to overcome increased inconvenience to the customer.

The inclusivity of the baseline methodology is seen as another factor that impacts the ability to connect new assets. The benefits of a nomination baseline over a prescriptive baseline methodology is that the different approaches can be used for different asset types. This is seen as something that can encourage participation from a wider range of technology types.

Privacy and GDPR considerations were also seen as a potential barrier regarding the type of data that needs to be shared in order to participate in the trial. Aggregators felt that sharing data at portfolio level is preferred as it enabled them to tell their customers that their data would not be shared externally.

Aggregators also highlighted several ways for encouraging customer participation to maximise the benefit they see from participating in the trial. One such suggestion was to allow stacking of revenue from the trial with other service. To achieve this, gate closure would ideally be adjusted so that it aligns with value of flexibility so assets can tailor how much capacity they are bidding into each market to maximise returns.

Finally, one aggregator also observed that raising the free bids price cap in Phase 2 of the trial had a positive effect in raising public interest on flexibility and increased the incentive to encourage participation.

4.8.3.3 Market Procurement Timelines

Procurement strategies have differing procurement timelines; aggregators were asked for their opinion on the comparison of long-term and short-term market procurement. The FUSION trial required aggregators to declare their available capacity 6 months in advance when they signed the FSA, which aligns with the ENA ONP's Flexibility Procurement.

Aggregators commented on how the timelines for flexibility procurements in the trial have impacted their ability to recruit additional customers. Gridimp stated their preference for declaring their availability volume less than 6 months ahead. They felt that this would be helpful in encouraging participation because contracting far in advance restricts stacking with other markets (e.g. NGESO's

Demand Flexibility Service and SP Energy Networks' BaU flexible services) and would therefore reduce customer willingness to participate.

Their preferred approach was for a framework contract with availability declarations within the contract window. For them, this would ideally this would be a weekly declaration of what is available however they noted that even one month ahead would be beneficial for them in being more certain about which assets are available. This proposed arrangement overcomes the difficulties in predicting faults that impact their ability to deliver and provides smaller assets with greater flexibility about when they participate in the flexibility market.

4.8.3.4 Effectiveness of Free Bids Mechanism at Encouraging Participation

The USEF Free Bids mechanism allows new flexibility to be added as and when it becomes available. The USEF Free Bids mechanism allows for additional revenue outside of long-term contracts which gives more revenue to uncontracted assets as they join the market. This in turn, means more revenue opportunity for aggregators and makes the recruiting of new flexibility providers easier. Free Bids also allow the DSO to refine their procurement needs nearer delivery and avoid paying availability for the term on longer contracts.

Aggregators advised that despite their attractiveness to new assets, the current contractual arrangements and payment structure do not make sufficiently incentivise the submission of free bids. While aggregators appreciate the mechanism as an extra revenue source, their focus in Phase 2 of the trial was on fulfilling their obligations on availability.

Ultimately, the trial has shown that the free bidding concept works but the current market and system is not mature enough yet to fully leverage this mechanism. As the mechanism matures in the next stages of the trial, the question of whether it encourages wider participation will be explored.

4.8.4 Conclusions and Learnings

Summary of key outputs from questionnaire responses are as follows:

- One aggregator has found challenges in bringing on additional flexible assets in Phase 2 of the trial to meet their contracted availability volume. They noted that the technical challenges associated with enabling new assets and dealing with businesses with multiple subcontractors has increased the lead time of new connections.
- It was also noted that the requirement to state the available capacity six month ahead of delivery is making it more challenging to bring on new customers due to uncertainty in revenue, penalties, sub-optimised flexibility use. Short term markets would allow aggregators to be more certain about the availability of flexibility, and would make it easier to onboard new assets that are considered non-firm capacity into the market, which in turn would enable more efficient use of flexibility and more revenue to their customers. Note that this section does not refer to contract duration between aggregator and customer but rather between DSO and aggregator.
- Aggregators continue to recommend that the balance between utilisation and availability incentives could be improved by rewarding delivery over availability.
- Notification time between FlexOrder and delivery is important to customers. Ordering day ahead provides customer with more visibility of when their assets will be utilised and is therefore more appealing to them.
- While it is recognised that USEF's free bids mechanism provides more opportunity for revenue through enabling additional income outside of long-term contracts, FUSION's free bid system is not mature enough yet to fully leverage this mechanism therefore its ability to attract new customers is not clear at this stage but will continue studied as the trial develops.

4.8.4.1 Next steps for this objective

The next steps for this this objective to explore the commercial mechanisms for encouraging wide customer participation are:

- Review the question of whether free bids encourages wider participation of assets after free bids become more commonly used in the trial.
- Project FUSION should continue to work with aggregators to consider how best to encourage participation of domestic assets and the impact of various commercial mechanisms. Direct feedback from domestic customers would help to understand their experience of the trial further.

4.9. ADDITIONAL LEARNING – DEMAND TURN UP

SP Energy Networks explored the possibility of engaging with another aggregator to trial a demand turn-up service. Although USEF supports this concept, the FFP was not designed to place orders for demand turn-up, nonetheless, the test was conducted and demonstrated that it could be used to do so.

SP Energy Networks trialled this use case by using a hypothetical congestion point to which a simulated aggregator with a hypothetical DER portfolio was allocated. The role of the simulated aggregator was fulfilled by SP Energy Networks using the AGR-simulator (plug-in) developed by OrangeNXT.

Using the FFP, the DNO created a flex request at the hypothetical CP in which the sign to request for demand turn-up was inverted. The simulated aggregator was then able to respond to the FFP, via the AGR-stub, with a FlexOffer, which was subsequently ordered by the DNO.

This trial demonstrated that, whilst they were not designed for this purpose and do not offer the same quality of user experience in this configuration, the FFP and the AGR-stub can be configured to trade demand turn-up services.

This is positive news because it means that:

1. Not only can the AGR-stub provide a means for aggregators to participate in a USEF flex market (like FUSION) without having to implement any IT development of their own, but also;
2. They can use this configuration to trade both demand turn-down and demand turn-up.

5. Stakeholder engagement and wider impact

This section contains a summary of the interactions of the project FUSION with other initiatives, projects or organisations including its participation in the Energy Innovation Summit and its interaction with the key stakeholders ENA OP, Ofgem and Shapeshifter.

5.1. FUSION'S PARTICIPATION IN THE ENERGY INNOVATION SUMMIT

SP Energy Networks was a headline sponsor for the Energy Innovation Summit that was held in the Glasgow SEC Centre celebrated at the end of September 2022. This summit provided a valuable opportunity for stakeholder engagement, project exposure and promotion. A breakout session on the topic of flexibility was held in which the FUSION project was presented, explaining its learnings to date.

5.2. INTERACTIONS WITH THE ENA ONP

Project FUSION supported ENA ONP Product 5 (P5) under Workstream 1A to develop and assess the potential implementation of the 'primacy rules,' that will be used to manage potential conflicts between ESO and DSO services.

This study focused on the interaction between Short Term Operating Reserve (STOR) providers and Active Network Management (ANM) generators in the same area where opposite instructions could be issued by the ESO and DNOs. It explored the use case in which the ESO instructs a STOR generating asset to increase MWs, and subsequently the DNO curtails a different generator through ANM, which counteracts the ESO instructed STOR service.

The objective of this project was to quantify the economic impact on all parties involved of the primacy rules that would mitigate this conflict, to help ENA members understand which rules deliver the most efficient outcome for the end consumer.

This exercise concluded in a separate report that will be made publicly available on the FUSION website, therefore this report does not address the results of the study.

5.3. INTERACTIONS WITH OFGEM

Project FUSION meets with Ofgem to discuss the project progress and share insights on interim learnings and next steps. In early December 2022, Project FUSION will present a 'show & tell' to an audience of Ofgem representatives, which will comprise a presentation of interim learnings and a Q&A session. In November 2021, a similar session was held for the previous trial phase.

5.4. INTERACTIONS WITH SHAPESHIFTER

Project FUSION representatives attends the monthly TSC SHAPESHIFTER meetings. In these meetings, the SHAPESHIFTER (formerly known as UFTP) user community discusses improvements to the protocol, change requests, processing of the changes in the protocol and specifications, etc.

Project FUSION has discussed multiple changes requests based on the trial experience. For details regarding changes request refer to Section 4.6.

6. Next steps

The FUSION trial will run until end of March 2023. Once finalised, all data will be updated and included to the current analysis, as well as the next steps identified in the different objectives. Next to that, Project FUSION will address the remaining objectives on:

- Cost benefit analysis
- DSF potential;
- Business case of USEF-based flexibility;
- Efficient DNO network management; and
- Coordination with the ESO

The cost benefit analysis objective is currently being finalised and a separate report is expected in February 2023.

The objective on "coordination with the ESO" will be based on an ongoing trial between SP Energy Networks and the ESO and will conclude with a report of findings due February 2023.

Finally, the dissemination of the learnings of the project will conclude with a closing report in November 2023, when the end date of Project FUSION is set.

Glossary

Term	Definition
Aggregator (AGR)	A service provider that contracts, monitors, aggregates, dispatches and remunerates flexible assets at the customer side. (USEF terminology)
Availability Payments	Payments made for being available to deliver the contracted Flexibility Service during a specified time period (described as the 'Service Window').
Combined Heat and Power (CHP)	The use of a heat engine or power station to generate electricity and useful heat at the same time.
Common Reference (or congestion point repository)	USEF defines the Common Reference as a repository which contains information about connections and congestions points in the network.
Common Reference Operator (CRO)	In USEF, the CRO is responsible for operating the Common Reference. The CRO's role is to ensure the publication of both the DSO flexibility requirements and the associated flexibility assets in each congested point as well as the standardisation of this publication for all distribution areas.
Congestion Management	The avoidance of the thermal overload of system components by reducing peak loads. The conventional solution to thermal overload is grid reinforcement (e.g. cables, transformers). Congestion management may defer or even avoid the necessity of grid investments.
Constraint Management Service Provider (CMSP)	A provider of constraint management services to a DSO or the TSO. This is a USEF role and is not currently used in GB. This role takes on specific responsibilities in communicating and coordinating flexibility transactions with the ESO and DSOs, to ensure effective deployment of flexibility as well as effective management of network constraints. Responsibilities also involve ensuring efficient dispatch of flexibility to maintain the safety and reliability of the networks.
D-programmes	Aggregator forecast of the amount of energy to be consumed or produced at a given congestion point.to be shared with DSOs in congested distribution network areas.
Delivered Flexibility	The term delivered flexibility is used solely for flexibility that meets the FlexOrders. It is the amount of the ordered power that was delivered during the

	activation window measured by looking at the change in power from the baseline to the meter readings and capping it at the power output agreed in the FlexOrder
Distribution System Operator (DSO)	As defined in DIRECTIVE 2009/72/EC: A natural or legal entity responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.
Flexibility	Ability of an asset or a site to purposely deviate from a planned or normal generation or consumption pattern.
Heating, Ventilation and Air Conditioning (HVAC)	The use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space.
Market Coordination Mechanism (MCM)	The Market Coordination Mechanism in USEF includes all the steps of the flexibility trading process, from contractual arrangements to the settlement of flexibility. USEF splits the flexibility trading process in five phases and describes the interactions between market participants and information exchange requirements in each phase of the MCM.
Prosumer	This role refers to end-users who only consume energy, end-users who both consume and produce energy, as well as end-users that only generate (including on-site storage). (USEF terminology)
Realised Flexibility	The total change in power from the baseline to the meter readings during the activation window.
Settlement Period	The time unit for which imbalance of the balance responsible parties is calculated. In GB is 30 minutes.
USEF Flexibility Trading Protocol (UFTP)	A protocol that describes the interactions for the exchange of flexibility between aggregators (or other flexibility service providers) and DSOs.
Utilisation Payments	Payments made to flexibility service provider for energy delivered as part of a Flexibility Service