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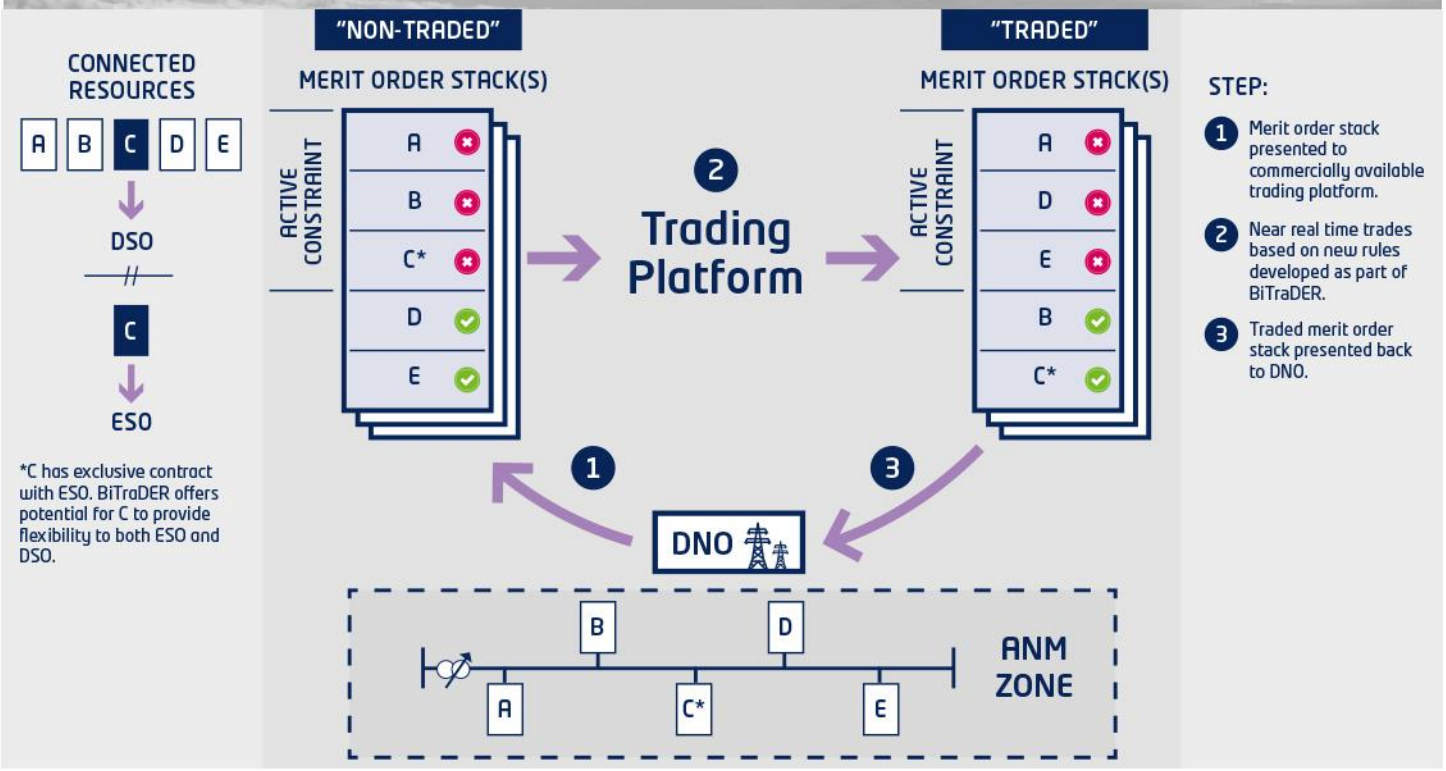
Bringing energy to your door

BiTraDER

Deliverable 2

Trials Plan, Trading Rules and Initial Specification Report

June 2023



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Contents

Glossary

ANM	Active Network Management - The use of distributed control systems to continually monitor network limits, and provide signals to curtailable connections or flexible services to modify outputs in line with these limits
API	Advanced Programming Interface – A type of software interface between two systems
Aggregators	Organisations that contract with a number of smaller organisations and use the collective capacity to trade in the flexibility market
Baseline	The point from which any delivery of flexibility is measured
BaU	Business as Usual
BESS	Battery Energy Storage System
'Buyer'	Party buying the ability to transfer their curtailment obligation to another connectee and accept a more favourable position in the merit order list
CB	Circuit breaker
Connectee	Any individual or company connected to the electricity distribution network
Constraint	A demand greater than network ratings or voltage outside statutory limits. In this definition demand is used in the context of the load on the network (including generation).
Curtailable connection	Connection arrangements which allow Electricity North West to signal, in real time, a curtailment of demand or generation when there are network overloads or restrictions affecting the network local to the connectee whilst the network is operating in an intact, system normal state. Connectees will generally be given a curtailable connection where offering a non-curtailable connection would require network reinforcement which has cost and time implications on them being connected
Curtailment	The turning off, or down, of a connectee's import or export to alleviate a constraint based upon contracted and agreed principles of available capacity
Curtailment obligation	The requirement for a connectee to provide curtailment. The specific details of this requirement will be stated in their connection agreement
DNO	Distribution Network Operator - An organisation that owns, operates and manages the electricity infrastructure that distributes electricity from the transmission network operated by the ESO, to end users (commercial and domestic properties).

Demand increase (flexible service)	A connectee providing a flexible service where the outcome is an increase in demand (this could be provided by either generator reducing export, or a demand connectee increasing import within their maximum import capacity limits)
Demand reduction (flexible service)	A connectee providing a flexible service where the outcome is a reduction in demand (this could be provided by either generator increasing export within their maximum export capacity limits, or a demand connectee reducing import)
EHV	Extra High Voltage – a voltage of 33 00V or 132 000V
ENWL	Electricity North West Limited
ESO	Electricity System Operator – An organisation that monitors, controls and actively manages the power flows on the electricity transmission network to maintain a safe, secure and reliable electricity supply. ESO is a natural monopoly in the flexibility market, acting as a neutral facilitator
EV	Electric Vehicle
Flexible services	Services purchased from a flexible service provider to provide demand turn down, and demand turn up to alleviate network constraints. These services are used to defer and avoid reinforcement, as well as to allow other customers to connect faster and cheaper to the network and can be provided from demand or generation
Flexible service provider	A demand or generation connectee providing flexible services to either the wholesale market or to the DNO and ESO
Flexibility	The modification of generation injection and/or consumption patterns, on an individual or aggregated level, often in reaction to an external signal, to provide a service within the energy system
HV	High Voltage - a voltage of 6 600V or 11 000V
I&C	Industrial and Commercial – businesses in the industrial and commercial sector
Merit order list	A list of connectees in a specific order for the ANM system to action
'N-1' conditions	N-1 means that is network is planned, and operated, such that the loss of any one element (e.g. an overhead line, a transformer, an underground cable) still allows the network to operate securely and to continue serving demand
NIC	Network Innovation Competition
Non-curtailable	Under system normal conditions, a connection which is planned and operated such that it should not be curtailed; however it may be curtailed in the event of the loss of any one or more elements (e.g. an overhead line route, a transformer, an underground cable)
Peer to peer trading	Trading between connectees, independent of the DNO or ESO
RTU	Remote terminal unit

SCADA	Supervisory Control and Data Acquisition
'Seller'	Party selling the ability to accept a curtailment obligation from another connectee, within the limits of their connection agreement

Executive summary

This report is the second deliverable for the BiTraDER (Network Innovation Competition) NIC project which is being delivered by Electricity North West Limited (ENWL) and its partners. The aim of this report is to explain the project progress to date with a specific focus on the trading rules design, initial specification of the end to end solution and the current plans for the trial phase.

It builds upon the previously delivered and published report for the BiTraDER project:

1 BiTraDER Customer Engagement and Trading Scenarios 30/11/22

The main objective of the BiTraDER project is to demonstrate how access to a neutral market allows connected resources to trade their obligations bilaterally, encouraging more of them to offer flexible services, increasing availability of flexibility and thereby reducing whole system costs.

The project currently remains on track to meet its aims, objectives, and all deliverables outlined within the full submission.

This report, and the detailed associated reports, explain the project progress to date including the following outputs:

- end to end trading rules,
- cyber security report,
- technical requirements for the trading platform,
- simulation trial plan and live network trial plan.

1 Introduction

As part of the UK's journey toward net zero, Distribution Network Operators (DNOs) are experiencing an increase in requests by customers to connect low carbon, renewable energy sources to the network. These connections can cause network constraints which are usually resolved through expensive, time-consuming and disruptive network reinforcement.

As a more cost-effective solution, DNOs have introduced curtailable connections and flexible services which, when used alongside advanced network automation algorithms such as Active Network Management (ANM), can control the customer's generation or demand output in real-time to resolve constraints.

Curtailable connections allow customers to connect to the network without the need for traditional reinforcement. Therefore, these connections are at lower cost, and can be delivered within shorter timescales than a 'non-curtailable' connection. When accepting a curtailable connection a customer accepts the obligation to curtail their asset's export or import, in response to a request from the DNO, under certain network conditions. This is referred to as a 'curtailment obligation' and the specific details are stated in the customer's connection agreement.

Although these connections are lower cost and quicker, many customers are hesitant to accept them due to the inherent risk of being curtailed, and the associated commercial risk. Instead, some customers prefer to pay more and wait for a non-curtailable connection with negligible risk of being curtailed. In the case of low carbon generation such as solar, owing to the high capital investment required to establish the facility in the first instance, customers need certainty of a high in-service utilisation factor, meaning they are particularly sensitive to the risk of curtailment and much less likely to accept a curtailable connection.

Additionally, customers can provide a 'flexible service' to the DNO by agreeing to increase generation output, or reduce demand, at times defined by the DNO in exchange for remuneration. Owing to the long-term commitment associated with a flexible service contract, some customers are similarly hesitant to offer this. The commitment can be perceived as a barrier if customers are unable to meet the contract requirements over a prolonged period of time (i.e., a year).

BiTraDER seeks to allow new and existing customers to mitigate the risks associated with curtailment obligations by enabling customers to trade their curtailment obligations bilaterally. BiTraDER will also provide an opportunity for customers to participate in flexibility on an 'ad hoc' basis, removing the risk associated with long term contracts and boosting liquidity in the market.

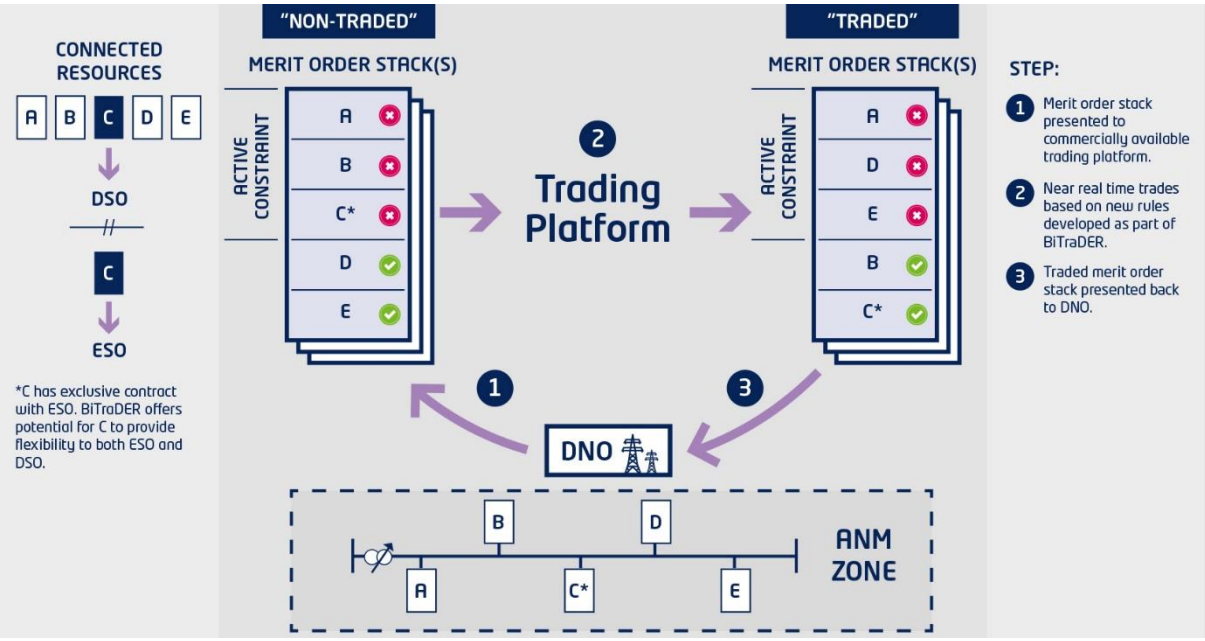
2 Overview of BiTraDER

BiTraDER will investigate, design, build and trial – on our live network – a brand new and highly innovative market allowing resources connected to the distribution network to trade their curtailment obligation bilaterally.

The project will assess current and future customers' appetite for bilateral trading, determine the data requirements to support operation of the market, design the interfaces needed to present all necessary information to the trading platform, develop the bilateral market trading rules determining what is and isn't a valid trade, explore the market's ability to operate in near real-time, and determine the functionality required to return the output of the market to the DNO and ESO systems for execution in real time.

BiTraDER is designed to facilitate independent trading, therefore ENWL will provide the necessary information to the market and receive the output of the market after close of trading. The project will examine the role of the market administrator and propose who might be best placed to operate the market in business as usual. Figure 1 shows the high-level illustration of the trading process as per the BiTraDER full submission.

Figure 1: BiTraDER illustrative method



BiTraDER will be completed in six phases, over a four-year period:

1. *Customer engagement* – engagement and recruitment of customers to inform the design of the trading rules and platform, during the design phase, and to participate in trading during the simulation and live trial phases.

2. *Design* – development of the core trading scenarios, market principles and trading rules, including validation and practical challenges associated with enabling trades. Design of the trading platform and end to end data architecture, taking into account cyber security and other associated risks. Capture of the technical requirements and the interface considerations for integrating the trading platform with the ENWL systems.

3. *Build* – build and test of the trading platform and data architecture using the outputs of the design phase. The acceptance criteria for testing will be developed during the design phase.

4. *Simulation trials* – a series of tests will be run using simulated network models and customer assets, allowing customers to participate in simulated trading of their curtailment obligations.

Following the simulation trials there is a 'Stage Gate' which provides the opportunity to ensure that the plan for implementation of the live trial is both reasonable and deliverable within the constraints of the approved project. Should the project pass the stage gate we will move to the live trial phase, otherwise we will progress immediately to project closedown and Business as Usual (BaU) transition.

5. *Live network trials* – a live trial of trading covering a specific area of the ENWL network, including the curtailment of assets connected to our network.

6. *Closedown and BaU transition* – analyse the costs and benefits of BiTraDER and produce a closedown report for dissemination. Develop the process for transition to BaU, provide training to internal planners and operational engineers on all new codes of practice, and publish a functional specification for BiTraDER.

3 Customer engagement

In February 2023 customers were invited to a workshop to gain in-depth feedback to inform the market design stage of the project. The discussions informed the trading rules design, detailed in section 4, and particularly those elements which need testing further with customers as part of the trials.

A brief outline of the discussion points is provided here with the full detail contained in the year 1 workshop report.

- *Utilisation payments* – the initial assumption was to base the market on utilisation payments only. However, customers expressed concern about this approach as other revenue streams may be given up to enable participation and if they are not curtailed they will not get paid.

- *Trading windows* – attendees flagged that the notice period should be as short as possible, allowing solar and wind farms to incorporate the latest accurate weather forecasts into the decisions to trade or not.

- *Settlement periods* – one customer stated that they would rather participate if there were longer periods of curtailment, for example if they had a window of six hours where they turned down they could plan something else for that time, such as maintenance.

- *Pay as bid vs pay as clear* – at the time of the workshop, the project team's thinking was that settlement would be based on a pay as clear market. There was discussion around the definitions, usage and outcome of the two approaches (pay as bid or pay as clear), with questions from customers on what was done in other markets.

- *Settlement* – view from customers was that payments should be based on what they are actually generating in that period rather than what they have the capacity to generate.

- *Price discovery* – there was a strong interest from the customers in the approach to price discovery. There were a number of questions around how price discovery would work, how the market would allow parties to figure out pricing and the impact of pricing on site design and investment.

- *Design roadblocks* – customers pointed out that some sites do not necessarily have the infrastructure in place to turn off within 24 hours' notice; they would need to send an operative to the site to turn them off. Removing this barrier would be complex and they would need to carry out a detailed analysis to understand whether it made sense financially to implement these changes to participate in the market.

- *Platform functionality* – a key barrier is the need to register for multiple trading platforms without certainty that they would use them all. If customers could access data on information such as clearing prices, or an estimate of the potential value, it would mean they are more likely to participate. However, customers did not want their data to be made public to a point at which they are identifiable. There was discussion on the ability to make the market data

available so that customers could make better informed decisions on participating in the market. Transparency is an important factor to customers.

4 Trading rules

BiTraDER project partner, AFRY, led the work to develop the conceptual trading rules. A high-level summary of the rules is given below with the full detail provided in the BiTraDER Trading Rules report.

4.1 Approach overview

Initially a literature review was conducted to ensure BiTraDER builds on learnings from previous research in this area. The literature review, highlighted four relevant key messages:

1. There is *existing work in this area which can built upon*.

2. *Technical ability and regulation are key considerations* in market design. It is important to consider, for the purposes of the project, the technical feasibility of the market design with ENWL's systems.

3. *Lack of value and complicated concepts are key barriers to entry* for participants in flexibility markets. The market design should be kept simple and trades should be designed to produce value for participants.

4. *Creating a baseline is difficult*, particularly for demand. If a baseline is required, it is beneficial to start from previous work in this area.

The existing curtailment process was reviewed in detail to understand the context within which the trading of curtailment obligations needs to be framed.

To develop the trading rules, AFRY considered several market design choices across a set of building blocks - a combination of the building blocks is used to create the overall trading arrangements. The building blocks focused on the key design questions, providing the foundations and structure of the overall market design.

4.2 Curtailment process

Currently, ENWL use a 'curtailment index' to determine the master merit order for curtailment with each asset assigned a curtailment index based on its security of supply and the voltage level where it is connected. The master merit order is constructed so that customers with a higher curtailment index are further up the merit order and therefore more likely to be curtailed.

When a constraint is active, the ANM system works down through the merit order curtailing customers until the constraint is resolved. As customers with curtailable connections are situated at the top of the merit order, they will be the first to be curtailed.

Following curtailment of an asset its curtailment index is then decreased by the hours or Mega Watt hours it has been curtailed.

4.3 Trading rules summary

Trading of curtailment obligations as envisaged in BiTraDER is an innovative concept, without an established prototype model to follow. Therefore, a range of assumptions have been made to provide

an initial framework within which to explore the concept of the trading rules. Figure 2 gives a summary of the key building blocks explored for the trading rules, associated questions and high-level decisions.

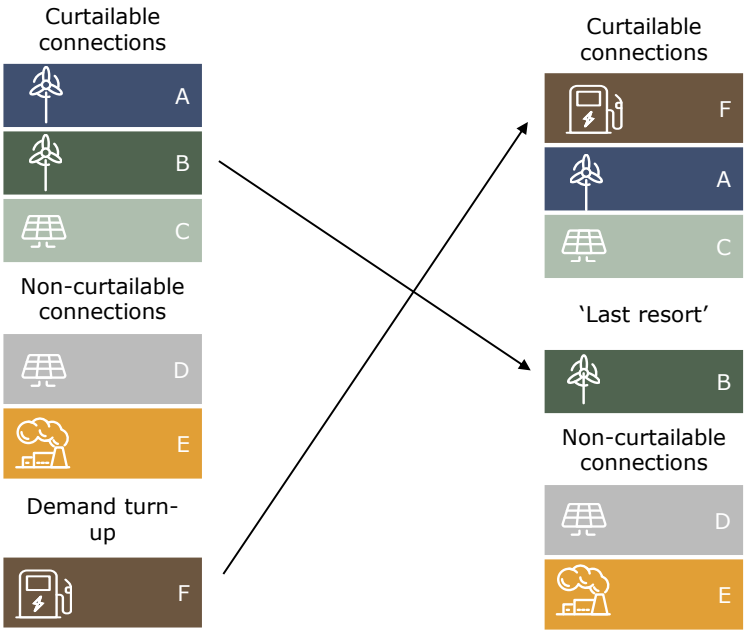
Figure 2: Key building blocks and associated questions

Building blocks	Questions	Current decision
Market process and timeframes	What are the timeframes for the market and associated processes / communications?	Day-ahead market with a single auction.
Product definition	What is the nature of the product being traded between parties?	Trading curtailment obligations.
Participant qualification	Which types of participant are eligible to trade as buyers and/or sellers and what are the prerequisites?	Curtailable connections can participate as buyers, and non-curtailable connections as sellers.
Network requirements	What information will be provided to the customer concerning the network situation and how will the different impacts on the network be accounted for?	All assets able to resolve the constraint will be treated equally.
Merit order trading principles	How are the position of the parties in the merit order affected by the trading?	See section 4.3.1
Payment structure and trade matching	What is the basis of payments from buyers to sellers and how are the trades matched?	See section 4.3.2
Volume traded	What is the basis for defining volume traded from the perspectives of buyers and sellers and different resource types?	Utilisation payments will be made for the volume curtailed against a self-declared baseline.
Dispatch and delivery	What are the instructions given by the DNO to the participants in the event of curtailment and how is delivery monitored?	Instructions given by ENWL and half-hourly metering will be used to assess the delivery of the action by the seller.
Settlement	What is the basis for determining and settling payments between trading parties? What would be the impact on curtailment index?	See section 4.3.3

4.3.1 Merit order trading principles

Using an excess generation constraint as an example, the merit order trading principles are described below.

Figure 3: Merit order trading principles



The merit order list for curtailment, as produced by the ANM, is shown on the left with curtailable assets (A, B, C) at the top, followed by non-curtailable assets (D, E, F). In this case, F can provide a demand turn up service. Note: we envisage demand turn up to be aggregator-led and are continuing development on how to represent this important market participant in the ANM system and on the merit order list, given the geographical disaggregation of their assets.

Asset B (the buyer) wishes to reduce its risk of curtailment and using BiTraDER successfully trades with asset F (the seller). Asset B then transfers its curtailment obligation to asset F and so secures a reduced risk of curtailment.

Using the proposed trading model, the traded merit order list is as shown on the right. Asset F moves to the top, and asset B moves below all other curtailable assets but above the non-curtailable assets.

The BiTraDER trading process is summarised below:

1. In advance of trading, customers will register on the trading platform and are required to have the functionality to receive a signal from the ANM system.

2. The ANM look-ahead will provide details on forecasted network constraints for the 48 hours ahead, with information specified in hour blocks. For each constraint, the information will include a list of assets connected to the constraint.

3. The pre-trade master merit order and the ANM look ahead list are sent to the trading platform.

4. The trading platform will filter the pre-trade master merit order list to produce a constraint specific merit order. Customers registered on the platform will be now able to see the details of the constraint.

5. Curtailable customers submit bids based on the amount they are willing to pay to reduce their risk of curtailment, i.e. move down the merit order. Non-curtailable customers submit

offers based on the amount they are willing to accept to increase their risk of curtailment i.e. move up the merit order. These bids and offers can be submitted up to gate closure in day-ahead timescales.

6. Following gate closure, trade matching will occur for each half hourly settlement period for the following day. The pre-trade master merit order is then re-ordered based on the matched trades. The traded master merit order is then sent back to the ANM system.

7. When the constraint occurs, the ANM system will instruct the first customer on the traded merit order to turn-down / turn-up and will then work its way down the traded merit order, as necessary, until the constraint is resolved. The ANM will create a report of the dispatch instructions and send it to the trading platform.

8. Following the event, the ANM dispatch report and customer metering will be used to carry out settlement:

    a. If the bids/offers include an availability payment, the buyers will pay this to any matched sellers regardless of whether constraint instructions were sent. If constraint instructions were sent and the seller did not respond in line with the trade, they will forgo some, or all, of the availability payment.

    b. If the bids/offers include a utilisation payment, the buyers will pay any matched sellers who were curtailed a payment based on the response, compared to a self-declared baseline, provided by the seller.

4.3.2 Payment structure and trade matching

The BiTraDER Trading Rules report describes three trade matching methods which will be explored during the trials:

1. Single part pricing: utilisation only market

2. Two-part pricing: a utilisation + availability market, ordered by the lowest availability

3. Two-part pricing: a utilisation + availability market, ordered by the lowest “all-in” (utilisation + availability)

In this case, the “all-in” price represents the total £/MWh price that will be paid in the event of utilisation. The availability price represents the minimum £/MWh price that will still be required as payment in the event of non-utilisation. Note: in the event of utilisation in this market the availability price is not paid in addition to the utilisation price, which is why the utilisation price is hereafter referred to as the “all-in” price.

4.3.2.1 Single part pricing: utilisation only market

For utilisation only the buyers and sellers submit one price component as part of their bid/offer. Bids are sorted from highest to lowest and offers are sorted from lowest to highest. The buyer with the highest willingness to pay is then matched with the seller with the lowest offer. This continues, working down bid prices and up offer prices until either bids or offers are exhausted or until there is no remaining bid with a price higher than (or equal to) a remaining offer. The market pays as cleared, meaning that all flexibility providers receive the price of the marginal bid.

The rationale behind this matching mechanism is that it minimises the complexity of price formation and discovery. The drawback is that early customer feedback has indicated that many potential traders will require a guaranteed availability payment to commit to this market day ahead.

4.3.2.2 Two-part pricing: ordered by the lowest availability

Buyers submit two prices representing the maximum that they are willing to pay in the event of utilisation and non-utilisation. Likewise, flexibility providers submit their minimum requirements for each of these categories. The buyer with the highest "all-in" (utilisation) price is matched to the seller with the lowest required availability payment provided that the buyer's all-in price is higher than the seller's all-in price.

This mechanism pays all-in/ utilisation payments as-bid, and availability as offered.

The rationale behind this matching mechanism is to minimise payments in the event of non-utilisation, while maximising the total revenue opportunity for flexibility service providers in the event of utilisation, to attract more players to the market. The draw-back is that the two-part price adds complexity.

4.3.2.3 Two-part pricing: ordered by the lowest all-in utilisation

The lowest all-in market follows a similar bid/ offer structure to the "Lowest Availability" market model, but the matching mechanism differs. This time, the highest buyer all-in bid is matched to the lowest sell all-in offer.

The market will be pay as offered.

The rationale behind this market is that this matching mechanism makes the market most attractive to new buyers of flexibility by driving down the all-in utilisation price over time. The draw backs are a similar level of bidding complexity to the previous two-part pricing model and that it prioritises cost savings to buyers of flexibility in utilisation events but does not minimise their downside in the event of non-utilisation. This draw back may be overcome with better curtailment forecasting. Moreover, unlike the previous matching mechanism, this mechanism does not maximise market value for the flexibility service providers.

4.3.3 Settlement

How different parties are affected by, or respond to, the constraint determines the payments between trading parties and how the curtailment index is updated.

4.3.3.1 Availability payment

If applicable, a successful buyer will pay a matched seller an availability payment, regardless of whether the curtailment occurred. If the seller under-delivers there are a number of actions which could be taken:

1. Don't adjust the availability payment and penalise the seller via the utilisation payment. This is easy to implement but could reward sellers by paying them for availability with no guarantee that they would be able to provide a useful action at the time of the constraint.

2. Use a pre-defined threshold. For example, if the seller has delivered 50% or more they get the full availability payment, otherwise they are considered to have failed to deliver and get no

availability payment. This avoids some of the issues associated with action one but requires a pre-defined threshold which may be difficult to objectively justify.

3. Pro-rata the availability payment. For example, if the seller delivers 0.5MW instead of 1MW, they get 50% availability payment for the full settlement period.

The project team agreed that action 3 was the most appropriate option.

4.3.3.2 Utilisation payment

When curtailment occurs, they buyer will pay a matched seller a utilisation fee. The value of this will be based on the curtailment duration and the scale of curtailment compared to the baseline and will be capped at the initial volume agreed with the buyer.

4.3.3.3 Curtailment index update

In line with the process detailed in section 4.2, the buyer's curtailment index will be decreased by the amount the matched seller was curtailed, following a curtailment action.

4.3.3.4 Counterparty

All settlement, including money transfers, is expected to be handled by the market operator. For the trials, the market operator role will be undertaken by ENWL and Electron. The project will produce a description of the market operator role along with recommendations for who is best placed to perform it in BaU.

4.4 BiTraDER use cases

BiTraDER deliverable 1 "Customer Engagement and Trading Scenarios" identified eight core use cases, as shown in figure 4, to test in the simulation and live network trials.

Figure 4: BiTraDER core use cases

			Buyers	
			Demand	Generation
			Curtailable	Curtailable
Sellers	Demand	Curtailable	1	5
		Non-curtailable	2	6
	Generation	Curtailable	9	13
		Non-curtailable	10	14

As part of the trading rules design, the use cases were reviewed which resulted in the removal of use cases 1 and 13. These use cases cover situations where the buyer's connection type is identical to the seller's, i.e. both the buyer and seller are curtailable in the same direction.

Allowing customers with identical curtailable connections to trade provides limited value but has negative externalities, such as:

- creating an incentive to sell services which do not help to resolve the constraint e.g. a curtailable seller accepts a buyer's curtailment obligation even though the pre-trade merit order states they would have been curtailed anyway.

- negatively impacting non-trading customers e.g. depending on the original merit order position of the seller a trade between two curtailable customers could result in a non-trading customer moving up the merit order increasing their risk of curtailment.

Therefore, curtailable connections with identical curtailment obligations have been removed as potential sellers for the trials resulting in the six uses cases, as shown in figure 5, to be used in the trials phase.

Figure 5: Updated BiTraDER core use cases

			Buyers	
			Demand	Generation
			Curtailable	Curtailable
Sellers	Demand	Curtailable	-	5
		Non-curtailable	2	6
	Generation	Curtailable	9	-
		Non-curtailable	10	14

5 Initial specification

BiTraDER project partner, Electron, worked with the ENWL IT team and our contractors, Enzen to develop the system architecture design and the functional requirements for the trading platform, including a cyber security assessment of the BiTraDER solution.

This section provides a summary of:

- the BiTraDER market process,

- the high level functional requirements for the trading platform,

- the high level system architecture and associated non-functional requirements and

- the cyber security assessment

More details are provided in the Trading Platform High Level Functional Requirements and the BiTraDER Technical Requirements reports.

5.1 Market process

The end-to-end BiTraDER market process as shown in figure 6 consists of six steps:

1. *Customer registration and asset onboarding:* to be eligible to trade customers (market participants) must complete the commercial and technical pre-qualification process at least 48 hours prior to delivery day. This process will only be required prior to the first trade unless there are changes to the registered assets.

2. *Trading:* market participants will submit bids or offers based on the constraint forecast information provided. The trading platform will match trades in line with the trading rules.

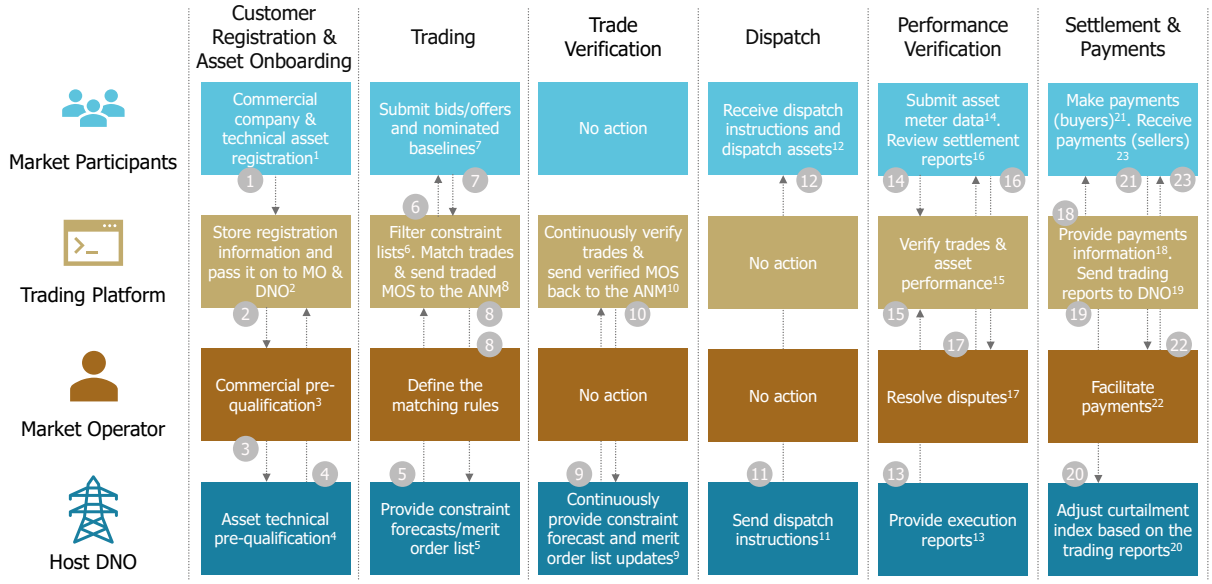
3. *Trade verification:* the trading platform and the host DNO's ANM system will verify that the trades are valid and can be dispatched on delivery day. This process will take place on delivery day, ahead of every settlement period.

4. *Dispatch:* the host DNO's ANM system will send dispatch instructions to market participants.

5. *Performance verification:* market participants will submit asset meter readings to the trading platform and the trading platform will then measure and verify trade performance. If any disputes arise, they will be resolved by the market operator.

6. *Settlement and payments:* the trading platform will provide payments information and market participants will make/ receive payments for the service provided.

Figure 6: BiTraDER market process



5.2 Functional requirements for the trading platform

Functional requirements define what the system should do, or the specific features and functionalities it should possess. Functional requirements use the MoSCoW (Must have, Should have, Could have, Won't have this time) prioritisation method to provide a clear understanding of the system's expected behaviour and functionality. For each step in the market process a detailed process was developed which resulted in the list of high-level functional requirements shown in figure 7. The list of

requirements is not exhaustive and will be updated in line with learning from the future stages of the project.

Figure 7: Functional requirements for BiTraDER

Process step	No.	Functional requirement	MoSCoW
Customer Registration and Asset Onboarding	1	Capability to provide company registration details and accept platform's terms and conditions (for participants).	Must
	2	Capability to create (and remove) user accounts in the platform (for participants, host DNO, market operator).	Must
	3	Capability to upload commercial and technical pre-qualification questionnaires to the trading platform.	Must
	4	Capability to approve or reject participant organisations from the market (commercial pre-qualification).	Must
	5	Capability to approve or reject participants' assets from the market (technical pre-qualification).	Must
	6	Capability to send notifications to participants, market operator, and the host DNO.	Must
	7	Capability to download commercial and technical pre-qualification questionnaires in their original formats.	Must
	8	Capability to edit technical asset data in the platform (for the host DNO).	Should
Trading	9	Capability to receive and store constraint look-ahead and master merit order stack files from the host DNO's ANM system.	Must
	10	Capability to filter constraint look-ahead and master merit order stack by participant.	Must
	11	Capability to notify participants about the upcoming trading opportunities.	Must
	12	Capability to accept bid/ offer submissions from participants, consisting of asset identifier field, price, volume, self-declared baseline, and time windows.	Must
	13	Capability to impose market deadlines, e.g., bid / offer submissions deadline and others.	Must
	14	Capability to match trades based on the agreed trade matching process.	Must
	15	Capability to re-order the master merit order stack, following trade matching.	Must
	16	Capability to return the "traded" master merit order stack to host DNO.	Must
	17	Capability to receive and store updated constraint forecasts.	Must

Process step	No.	Functional requirement	MoSCoW
Trade verification	18	Capability to compare the updated constraint forecast with the original constraint forecast.	Must
	19	Capability to cancel trades if one of the trade counterparties no longer appears on the constraint forecast.	Must
	20	Capability to update the master merit order stack following trade cancellations.	Must
	21	Capability to notify participants about trade cancellations.	Must
	22	Capability to return the updated master merit order stack to host DNO.	Must
Dispatch	23	Capability by the trading platform to issue dispatch instructions to participants via SCADA.	Will not have
	24	Capability by the trading platform to issue dispatch instructions to participants via API.	Will not have
Performance verification	25	Capability to receive and store participant meter data.	Must
	26	Capability to receive and store host DNO's execution reports.	Must
	27	Capability to carry out performance measurement and verification.	Must
	28	Capability to generate settlement reports and present them to buyers and sellers.	Must
	29	Capability to accept or reject settlement reports (by market participants).	Must
	30	Capability to update self-declared baseline volumes and meter data readings in the system (by participants and by the market operator).	Must
	31	Capability to record trades as completed (by the market operator after a dispute is resolved).	Must
	32	Capability to notify the market operator about rejected settlement reports and other events.	Must
	33	Capability to notify participants about settlement reports and other events.	Must
Settlement	34	Capability to generate trades reports and send them to host DNO.	Must
	35	Capability to generate invoices after trades are completed.	Could

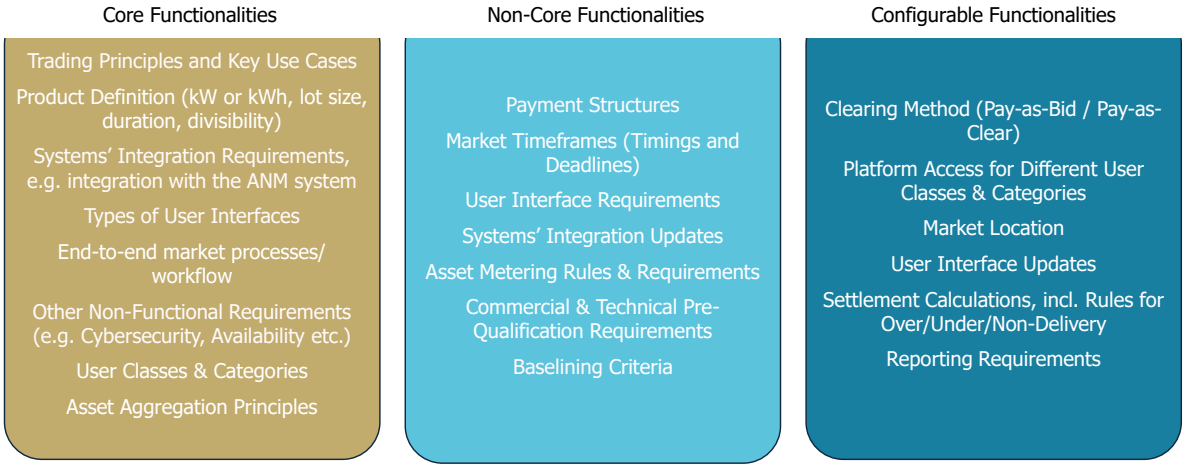
5.2.1 Practicalities of running market trials

The BiTraDER market will be tested in the trials detailed in section 6. One of the key objectives is to test different market configurations and platform functionality, so it is important that the trading platform is configurable, and the functionality can be updated quickly. To align the expectations of all

project stakeholders, the trading platform's functionality is categorised into three groups, the full list is shown in figure 8:

- *Core functionalities:* not configurable during the trials due to the time and effort required for any changes.
- *Non-core functionalities:* configurable during the trials but any configurations need to be planned in advance. The length of time required to configure these will depend on the complexity of the change.
- *Configurable functionalities:* quick to configure during the trials and they may still need to be planned in advance, especially when tested in a series of back-to-back workshops.

Figure 8: Trading platform functionality



5.3 Non-functional requirements

Non-functional requirements define the qualities or constraints that the system should possess, rather than specific functionalities. These requirements focus on the system's performance, usability, security, reliability, and other characteristics.

Non-functional requirements are crucial for ensuring the overall quality and effectiveness of the system. The key non-functional requirements applicable to BiTraDER are listed in figure 9. Note: all security related non-functional requirements are documented in the cyber security report.

Figure 9: Non-functional requirements

Grouping	As a	I want	So that
Audit	Internal audit	All users' access to BiTraDER systems are logged in their respective systems.	Logs are available to review users who accessed the system and assess any lapses if required.
Audit	Internal audit	All activities performed by users are logged and available for analysis.	To support any audit concerns that may arise.

Grouping	As a	I want	So that
Audit	Internal audit	Logs of high privilege access to systems granted should be available for audit purposes.	To support any audit concerns that may arise on why additional privileges are granted.
Audit	Internal audit	Data is stored and processed within the system depending on its criticality and confidentiality classification.	Depending on the data classification appropriate controls can be enforced.
Audit	Internal audit	Data should be archived in industry standard format and can be retrieved easily.	Data can be retrieved in a timely way as required.
Service	Service manager	The system is available for use 24 hours over 7 days a week, during the trial period.	End users can access the system to carry out their tasks with no limitations.
Service	Service manager	The system should have 99.99% availability during the trial period with predefined maintenance schedules.	System is available except for the predefined maintenance schedules.
Service	Service manager	The system should be able to automatically monitor its performance, availability, utilisation, failures etc. and raise alerts.	System availability and utilisation reports are available for review and take appropriate actions as required.
Service	Service manager	Trading platform should be made available for customers, market operator and DNO from their offices, homes, or anywhere within UK	All the required users can access the systems as per the predefined rules within UK.
Service	Service manager	Trading platform must have at least the following environments during build, testing and trials: production; test environment; development; training	Standard application development life cycle and service management processes can be adopted

Grouping	As a	I want	So that
Service	Service manager	All the environments should have the following response times: screen load time: <5s screen refresh time: <2s transaction processing time: <2s	BiTraDER systems are user friendly and respond to users in a timely fashion
Disaster recovery	Business continuity manager	Process, roles, and procedures are defined and documented for disaster recovery and business continuity. These are tested and the documents are updated prior to the trials.	Disaster recovery and business continuity processes are available in the event disaster occurs
Disaster recovery	Business continuity manager	BiTraDER system should have a recovery time objective of 1 hour maximum.	Trading platform can be recovered fully and made operational within this window
Disaster Recovery	Business continuity manager	BiTraDER system should have a recovery point objective of 0 hours to avoid any data loss of critical trading transactions between participants.	No data is lost in the event a disaster occurs
Disaster recovery	Business continuity manager	BiTraDER system must be capable of handling data storage of 0.5TB	All data storage needs can be met for the trial period
Usability	Customer	Trading platform should work on all supported browsers	Users can access the platform from their browser of choice

5.4 System architecture

As part of this phase of work, we have undertaken initial logical systems architecture development which designed and defined the logical structure and components of BiTraDER.

This created the conceptual model, figure 10, and the associated logical interfaces list, figure 11, and represents the high-level structure and behaviour of the system. It includes the major system components, their interactions, and outlines the data flow between them.

Figure 10: High level system architecture

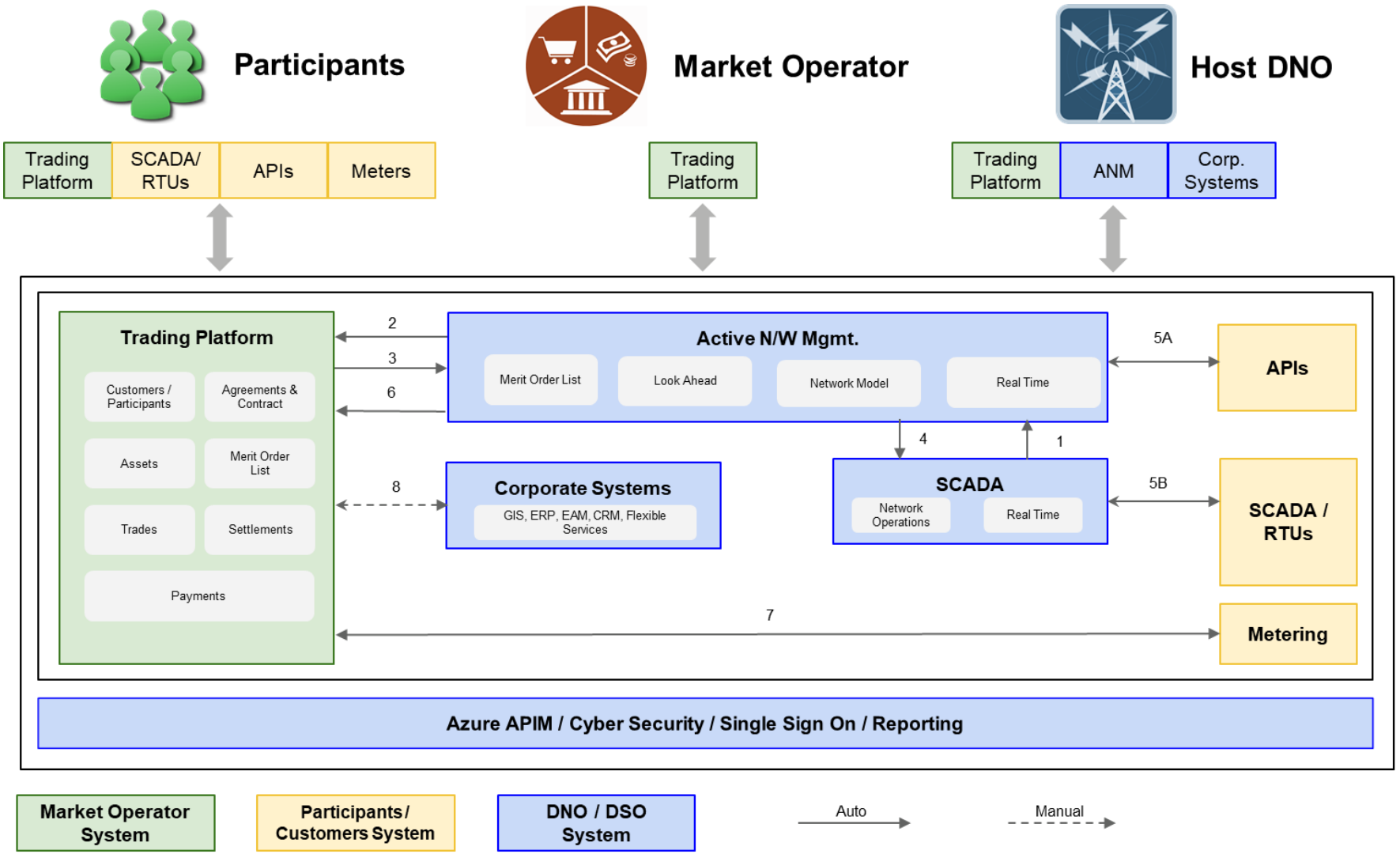


Figure 11: BiTraDER logical interfaces list

ID	Source System	Target System	Direction / Auto	Message
1	SCADA	ANM	1-way / auto	Available resources list / real time operational assets
2	ANM	Trading Platform	1-way / auto	Initial merit order list
3	Trading Platform	ANM	1-way / auto	Traded merit order list
4	ANM	SCADA	1-way / auto	Execution command / switching sequence list
5A	SCADA	RTU	2-way / auto	Manage dispatch start & stop signal for curtailable assets
5B	ANM	API	2-way / auto	Manage dispatch start & stop signal for non-curtailable assets
6	ANM	Trading Platform	1-way / auto	Post event execution report
7	Metering	Trading Platform	2-way / auto	Volume of curtailment service delivered by the participants
8	Trading Platform	Corporate Systems	2-way / manual	Asset details validation, customer details, payments etc.

5.5 Cyber security

The architectural approach to cyber security has full traceability in a bi-directional way between what has been implemented and the origins of certain decisions being made.

Within the design process we adhere to cyber security standards and frameworks which contain obligatory security controls across physical, network, operating system, application, and data stacks. These controls must be met in order to reach compliance with the particular standard and thus become measurable.

In implementing these controls, we create architectural principles, which any given control may apply to one or more principles. The principles apply the security controls to business risk, technical, and user requirements, which in turn inform the design.

In terms of BiTraDER, the following staged approach applies:

Figure 12: BiTraDER cyber security approach

BiTraDER deliverable	Cyber security deliverable	Rationale
D1 – Customer engagement and scenarios	None	Initial engagement with customers to determine the appetite for the peer to peer trading model
D2 – Trading rules and technical requirements (including business process maps and information models	Business impact assessment	Business processes are mapped such that key business impacts can be analysed
	Threat analysis	There are existing threat models that can be applied to the documented BiTraDER business processes
	Security principles	These are generic and are applied across all projects
	Security requirements	These are based on ISO 27001 standards
D3 – Trading platform design	Risk assessment	Risk assessment needs IT assets to be determined as part of the design phase
D4 – Architecture build	Penetration testing	The built architecture is tested from a security perspective to ensure that the security requirements have been met

5.5.1 BiTraDER cyber security report

The information contained within the full BiTraDER cyber security report contains sensitive information that could be used by an adversary. The full report can be provided to parties who require it to conduct their duties delivering the project.

6 Trials plan

The BiTraDER submission and associated project plan detailed two stages of trials:

i. Simulation trials which run from August 2024 to December 2025.

ii. Live network trials which run from May 2025 to January 2026.

Following discussions with the project team we have decided to introduce a third trial stage:

iii. Mini trials which will run from January 2024 to March 2024.

The following sections articulate the aim of each stage along with details of the scenarios and tests which make up the trials and the site selection criteria for the network trials. It should be noted that the trial plans are subject to change based on learning from customer engagement and from the earlier trial stages. Any changes to the trial plans will be highlighted in future deliverables.

6.1 Mini trials

When developing the trials, we recognised the value in testing some of our decisions on market design, such as payment structures, and to conduct some early price discovery through engagement with customers.

Therefore, we added an additional, cost neutral, mini trial stage which will be developed by the project team. This stage will better inform the trading platform design and facilitate the success of the simulated and network trials. The mini trials are important to ensure the preliminary stages of the market design is satisfactory to customers thereby giving the best chance of the project progressing to business as usual.

A 'Mini Trials' platform has been developed to accomplish this task. It is anticipated that a handful of experienced traders will participate in these trials to test realistic network constraint scenarios with the designed market principles. The customer will experience the role of both buyer and seller and have assets of different technology types. The feedback from this can then be carried forward to further assist in the development of the simulation trials.

6.1.1 Network

The scenarios to trial are spread between a High Voltage (HV) and Extra High Voltage (EHV) network designed to replicate a typical arrangement in the ENWL region.

The HV network consists of radial feeders with interconnected backfeeds between different primary substations or different bus sections on the same primary substation (see figure 13). A primary substation generally consists of two transformers with associated busbar sections. The Normally Open Points (NOPs) are represented by the green dashed line. The EHV network supplies the primary substations via transformer feeder circuits arranged as a singular feeder or as a meshed arrangement to supply multiple primaries (see figure 14). These are also usually fed by two transformers with associated busbar sections.

It is assumed that the theoretical assets connect onto a busbar via a metered Circuit Breaker (CB) with the facility to be tripped or have its input/output altered should a real time constraint occur. The technology type for each asset differs with each scenario along with the type of constraint.

Figure 13: Sample HV network mini trials platform

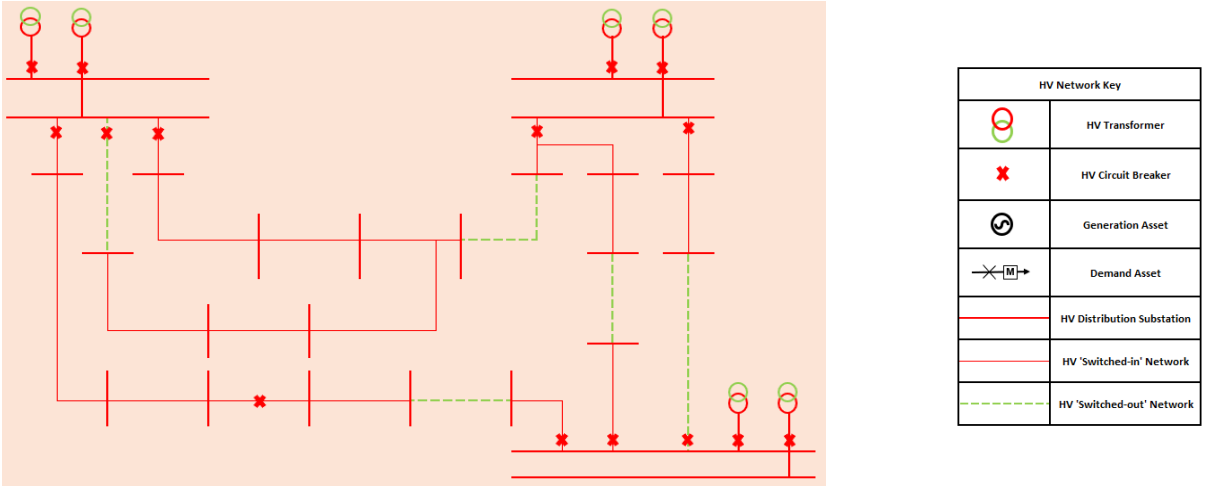
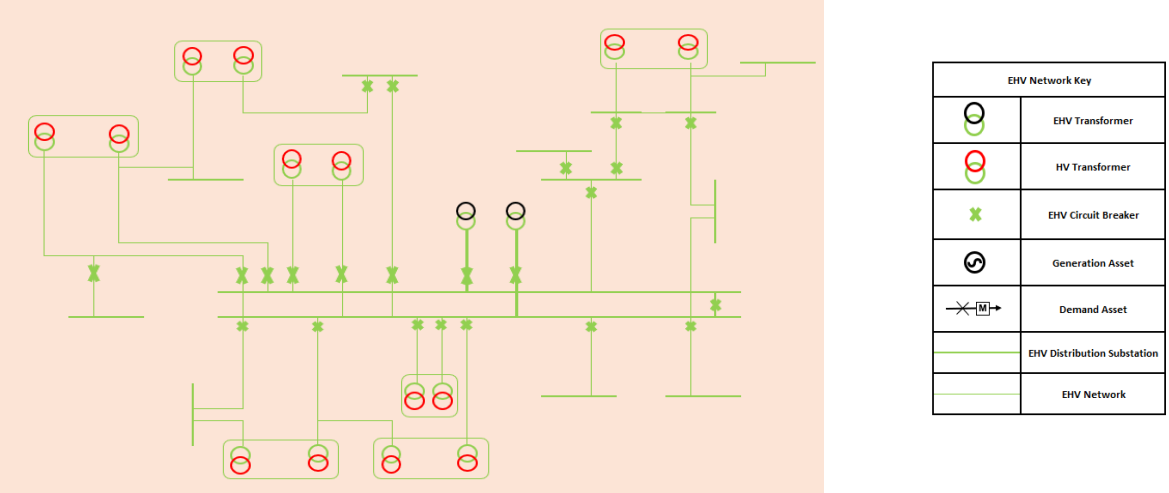


Figure 14: Sample EHV network from mini trials platform



6.1.2 Trial scenarios

In the mini trials we plan to use the scenarios detailed in figure 15 to test the different elements of the trading rules – these scenarios maybe refined ahead of the trials based on project team discussions.

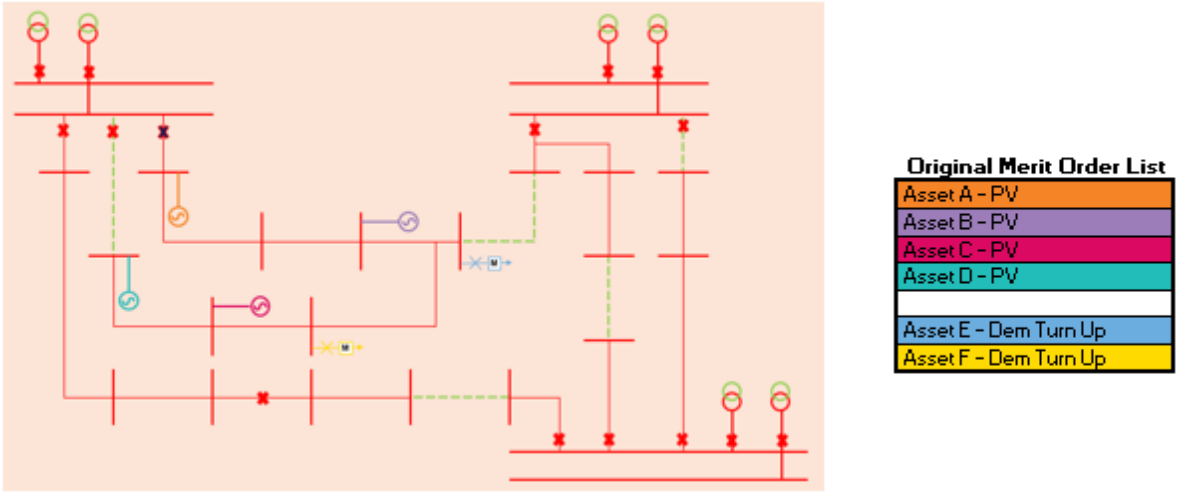
Figure 15: Constraint scenarios

Scenario	Constraint Type	Description
1	Generation (HV)	High level of solar generation at peak sun hours combined with low minimum summer demand causing predicted reverse power flow limits through the associated network feeder CB
2	Demand (HV)	High level of battery charging at night during cheap import tariffs causing predicted overload on transformer incomer CB
3	Generation (HV) Nested V1 – seller not helping	High level of wind generation during winter causing predicted reverse power flows on the associated transformer incomer CB and mid-point CB
4	Generation (HV) Nested V2 – buyer off the hook	Same scenario as 3 but the assets are ordered to demonstrate a different nested constraint
5	Demand (HV) Topology Change V1	The assets have traded for a predicted demand constraint but a change in network topology inhibits completion of the trade
6	Demand (EHV)	Multiple commercial demand customers across the EHV network cause a predicted constraint on the transformer incomer CB
7	Generation (EHV) Topology Change V2	The assets have traded for a predicted demand constraint but an outage on the network occurs and is not resolved before the trading period

6.1.2.1 Scenarios one, two and six

Scenarios one, two and six demonstrate one constraint and assume there are no changes in network topology leading up to the trade or during the 30-minute trading period. These are ideal scenarios whereby provided the buyers and sellers commit to the trade should not encounter any risk of the trade becoming invalid. The network diagram and merit order list for scenario 1 is shown in figure 16 as an example.

Figure 16: Scenario one

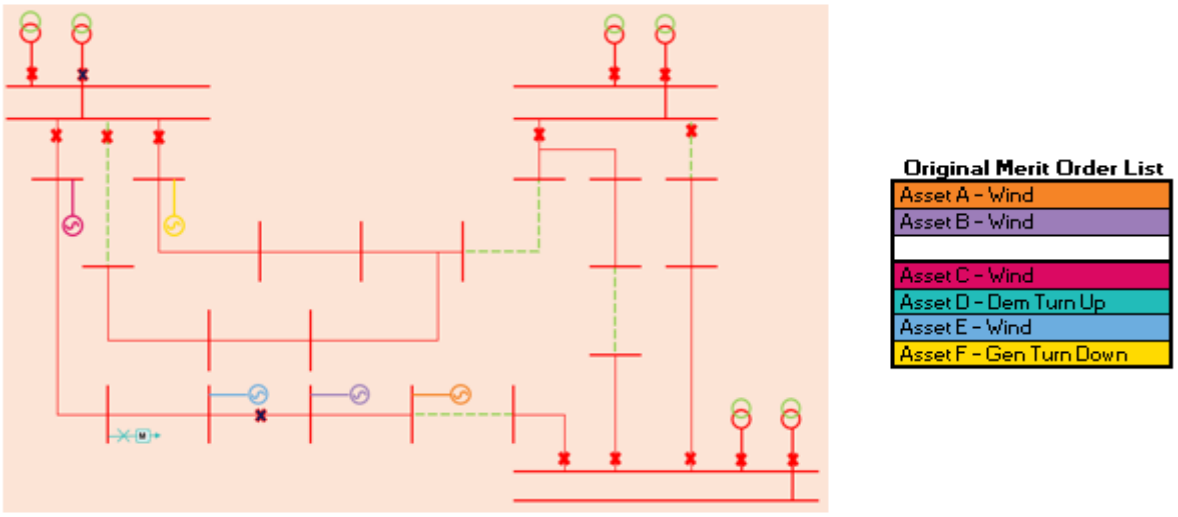


6.1.2.2 Scenarios three and four

Scenarios three and four demonstrate a nested constraint where the assets are placed onto a HV feeder with a mid-point CB. A constraint is predicted on both the mid-point CB and the transformer incomer CB leading to a situation where all assets could participate in a trade for the transformer incomer CB but only the assets after the mid-point CB could participate for the constraint at this CB.

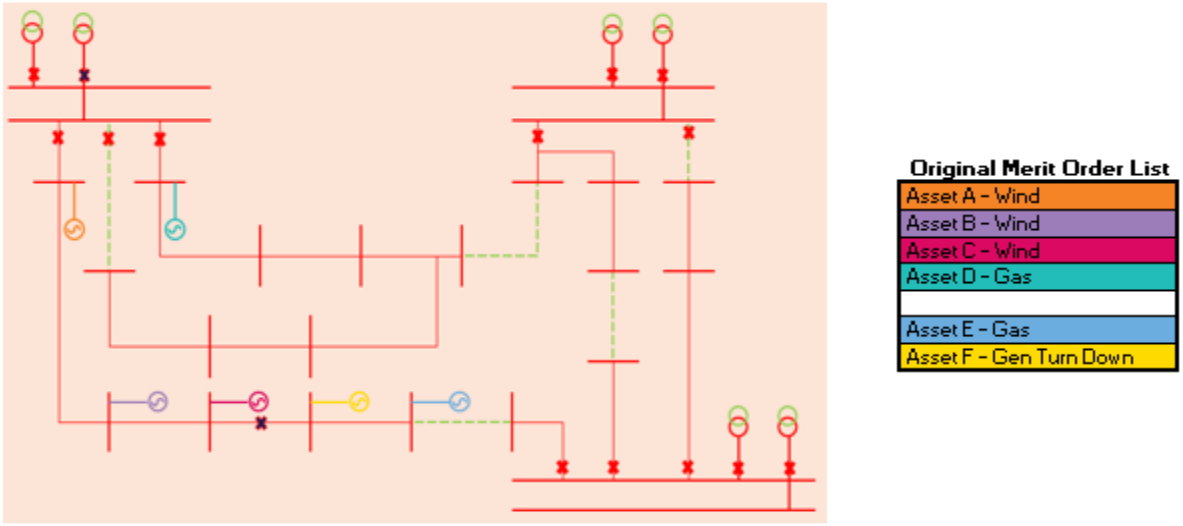
Scenario three – seller not helping: In this case, figure 17 the sellers are not affected by the constraint on the mid-point CB. Only the orange and purple curtailable generators sit behind the mid-point CB. If either of these two generators trade their curtailment obligation based on the constraint at the transformer incomer and the mid-point CB trips, the seller cannot assist in preventing the buyer from being curtailed.

Figure 17: Scenario three – nested constraint (seller not helping)



Scenario four – buyer off the hook – the network is the same as scenario three, only now the sellers sit behind the mid-point CB, figure 18. Again, if a trade took place for the constraint on the transformer incomer CB and the mid-point CB trips, in this instance the buyer would stay online, gain a more favourable position in the merit order and avoiding any payment to the seller.

Figure 18: Scenario four – nested constraint (buyer off the hook)



A key question to ask the customers at the trials regarding the nested constraint is what, if any, forms of compensation would be preferred if a nested constraint occurred. This could either be in the form of financial compensation or an update to their curtailment index. It is important to note that even though a trade occurs for one constraint with an associated merit order, there is a master merit order list which is updated effectively for all constraints.

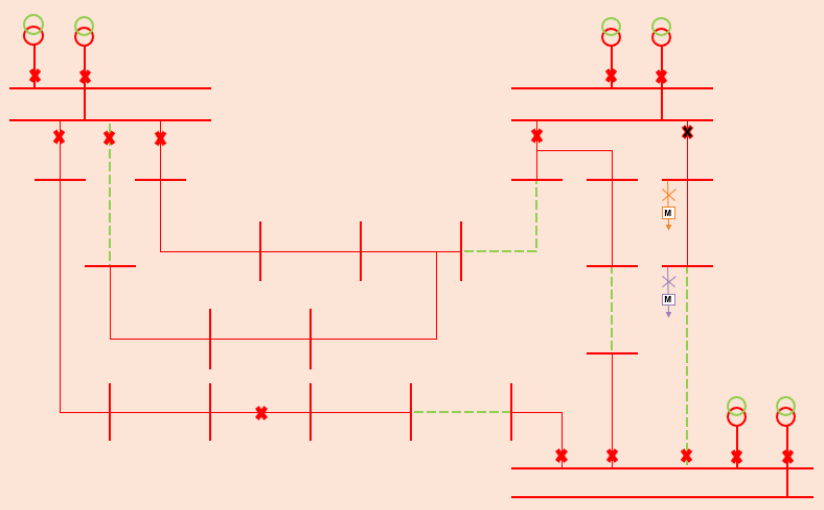
6.1.2.3 Scenarios five and seven

Scenarios five and seven demonstrate a change in the network topology. This can happen following a fault on the network which may then result in network reconfiguration and cause the assets to be fed from a different supply point. In this eventuality the trade would become invalid. This is demonstrated

in figures 19 and 20, where two demand assets trade with each other for a predicted demand constraint from the primary with the constrained CB.

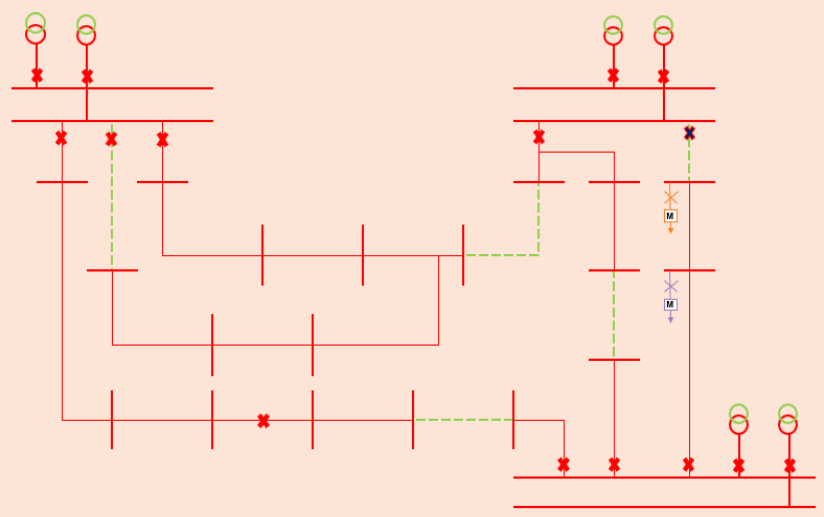
Figure 19 shows the network for scenario 5 without any faults or arranged outages and is therefore running normally. The constraint, which is on one of the CBs is highlighted in blue. The feeder currently supplied from this CB is shown in red with the alternative supply (backfeed) from an adjacent primary represented by the green dashed line.

Figure 19: Scenario five - change in network topology (pre-fault)



In Figure 20, a fault has occurred on the feeder between the constrained CB and the next switching point. To isolate the fault this feeder has now been switched out and the network reconfigured to restore supplies using the backfeed from the adjacent primary. The network is now said to be running abnormally. The original circuit is now represented by the green dashed line and the new backfeed circuit which has been switched in is represented by a solid red line.

Figure 20: Scenario five - change in network topology (post - fault)



If the change in topology happened during the half hour delivery period, a partial payment could still be due as the assets were available / curtailed for part of the period.

Both the change in topology and nested constraint scenarios demonstrate the limitations of the trading model and thus it is important to understand the customer's reaction and gather feedback. As the market model is new, it is important to increase the momentum of liquidity to enable trading to take place. By gauging customer reactions to some of the negative aspects of the market conditions, it could predict how likely this favourable momentum will be.

It should also be emphasised to customers that as the constraints are based on probability, there is a chance that they may not occur, leading to no payments taking place. It will be important again to gather customer feedback on this. One option to mitigate this would be to offer probabilities associated with each constraint, however, currently the ANM system does not cater for this. Availability payments have been introduced into the payment structure as an option to alleviate this and encourage sellers into the market.

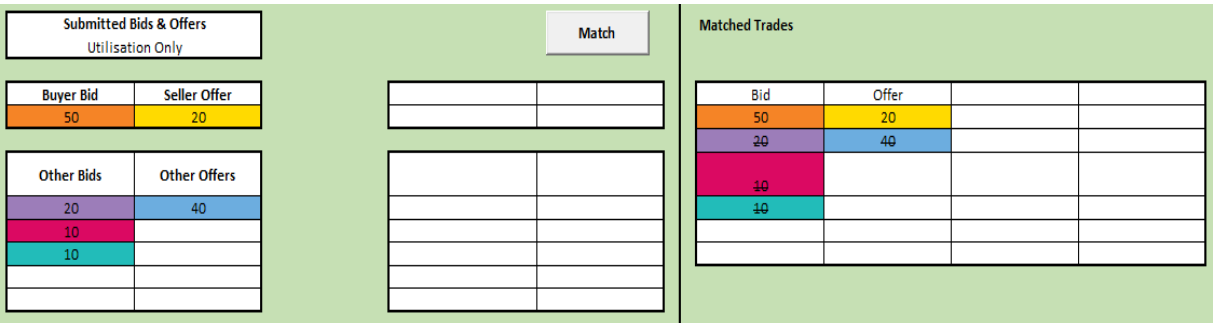
6.1.3 Payment structure

As described in the section 4.3.2, there are three trade matching methods to be trialled:

1. Single part pricing: utilisation only market
2. Two-part pricing: a utilisation + availability market, ordered by the lowest availability
3. Two-part pricing: a utilisation + availability market, ordered by the lowest "all-in" (utilisation + availability)

The trials will test all three payment methods for each of the scenarios. Figure 21 shows an example output from the matching in the mini trials platform for the single part pricing: utilisation only market.

Figure 21: Utilisation only payment matching



6.1.4 Price discovery

As each customer progresses through the scenarios, they will play the part of both the buyer and the seller, enabling a view from multiple perspectives on what the most favoured payment method is for each scenario.

The scenarios once complete can be run multiple times. At this point the customers will be familiar with the types of trades that they are submitting and how other buyers/sellers in the trials are behaving. This could lead to changes in the bids / offers between each scenario. This will determine the feasibility of price discovery in the lowest availability and lowest all-in payment structures. All trades will be recorded for review after the trials are complete.

6.1.5 Trial method

The mini trial platform can be shared between the customers and could be updated simultaneously as each customer makes a bid/offer. For each scenario a discussion would be initiated to gather thoughts on the result.

6.2 Simulation trials

Taking learning forward from the mini trials, it is currently proposed to run a two-day workshop for the simulation trials. By this time, the Electron trading platform will be developed and interfaced with the ANM system to allow simulated trading to take place. A suitably designed network will be constructed in the ENWL network management system to test scenarios similar to those in the mini trials.

Under normal circumstances the ANM look ahead function will predict a constraint for each half hourly trading window 48 hours in advance. This will need to be reduced for the trials to allow time for trades. The look ahead function could, for example, be reduced to predict a constraint half an hour in advance of the trading window. The customers could then assess the scenario and how much they would like to trade. Additionally, the trading window could be reduced to 10 minutes. This will allow the trials to run in a timely manner whilst providing enough time to add in any limitations on the network such as, simulating a fault which results in a change in network topology. Each look ahead and subsequent trading window would be manually triggered when the next scenario is ready.

6.2.1 System architecture testing

The simulation trials will be the first opportunity to test the end to end working of the platform and thus is a vital component of the project. Ideally, provided the end to end is working satisfactorily, it proves the ability to enable trading exists, albeit some rules of the trading rules may need to be amended depending on feedback. The ANM system can also be tested for the boundaries of operation, such as making sure the system copes with multiple ANM zones and constraints which are not all applicable to the trades.

It also provides an opportunity to test the interfaces between the ANM and the Electron platform with real customers. The curtailment index and merit order list can be viewed as an output from ANM before and after each trade to enable demonstration of the data flows. These outputs can be shared with customers to gather views on the trading principles.

6.2.2 Trading testing

During the trading window of each scenario, customer behaviour will be observed taking into account if a customer wants to trade and if so, how much. It is important to know what drives customers at this stage to carry out a trade to encourage liquidity in the market. Depending on the customers participating in the trials, it is like they will want to test trading based on their own situation. Ideally, the scenarios will run through each eventuality, so all customers feel they have had the opportunity to understand the effects on their assets and business.

There are a number of questions we would like to explore as part of these trials. This list is not exhaustive and will change with further project learning:

- What is the most appropriate length of trading block, do we have multiple blocks for each constraint?

- How close to the constraint can we trade?
- Which is the most appropriate bidding / payment structure?
- What happens at the time boundary of the trading blocks when curtailable parties may change?
- What is the most appropriate size of trading block?
- Do probability factors affect trading?

6.2.3 Settlement testing

For each scenario, each customer will be designated a running arrangement with how much import or export they are using/sending which can be used as a self-declared baseline for the trade. At this stage we will explain to customers about self-declared baselines and how the settlement and volume traded process works.

We will also explore the practicalities required for settlement in the network trials including understanding what data customers have and how can they send it to the platform. Additionally, we will test what happens if a seller does not provide the service they are being paid for.

We are exploring methods for making the simulation trials as realistic as possible e.g. using fake money for payments. Making the trials realistic could encourage the customers to think more about the bids and offers they submit as the likelihood of losing or gaining money would now factor into their decisions.

6.3 Live network trials

The live network trials provide the opportunity to test bilateral trading under real network conditions. Due to the uncertain nature of demand and generation it is impossible to guarantee constraints will manifest on the network and we may need to simulate them. However, it is important to note that even if the constraint is not real the actions and consequences will be, allowing customers to understand how trading impacts them and whether this affects their appetite to trade.

Although we have initially identified the Harker/Hutton GSP network feeding the Cumbria Ring for the live network trials, this selection is still under consideration as other better candidates may arise during the project lifetime.

6.3.1 Site selection

The Cumbria ring is an extensive 132kV network around Cumbria with two intakes from Harker and Hutton. This part of the network, owing to favourable environmental conditions, has a large number of connected, and accepted to connect, distributed generation shared across the two grid supply points and 12 bulk supply point groups. There is over 1GW of existing and proposed schemes, 50% of which is renewable generation from wind and solar.

Due the significant amounts of generation this part of the network is prone to constraints and is a suitable area for the live network trials. The Harker / network can be seen in figure 22 with the Kendal bulk supply point network in figure 23.

On both networks the generators can be seen along with several large commercial demand customers. A feasibility study was carried out to determine the potential demand side response customers on the Harker/Hutton network which identified customers who could be contacted and signed up to take part in the live network trials.

Figure 22: Harker-Hutton GSP network

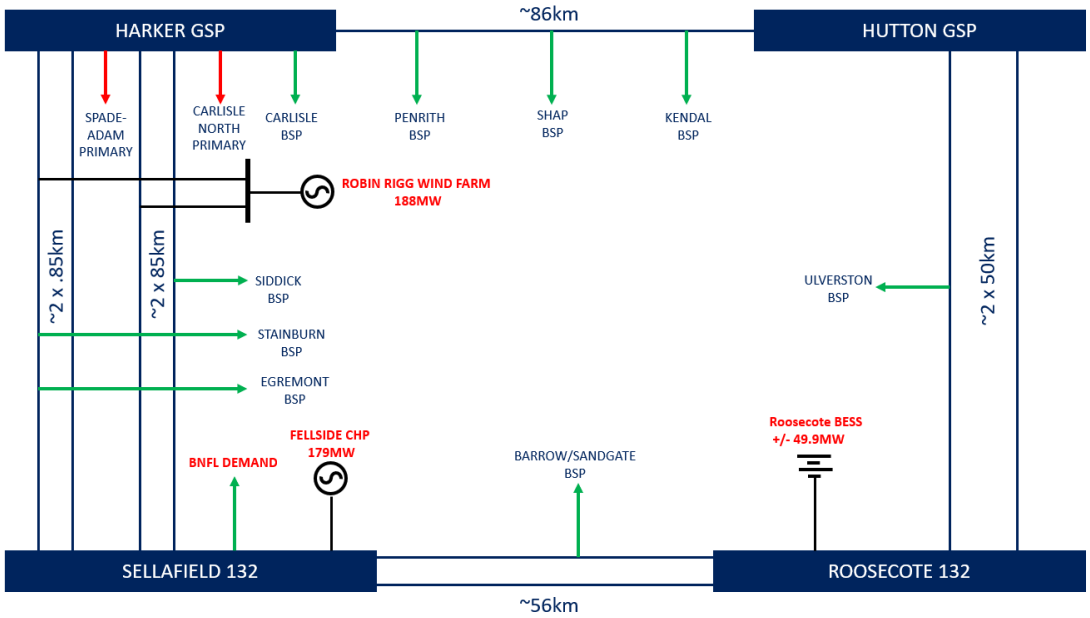
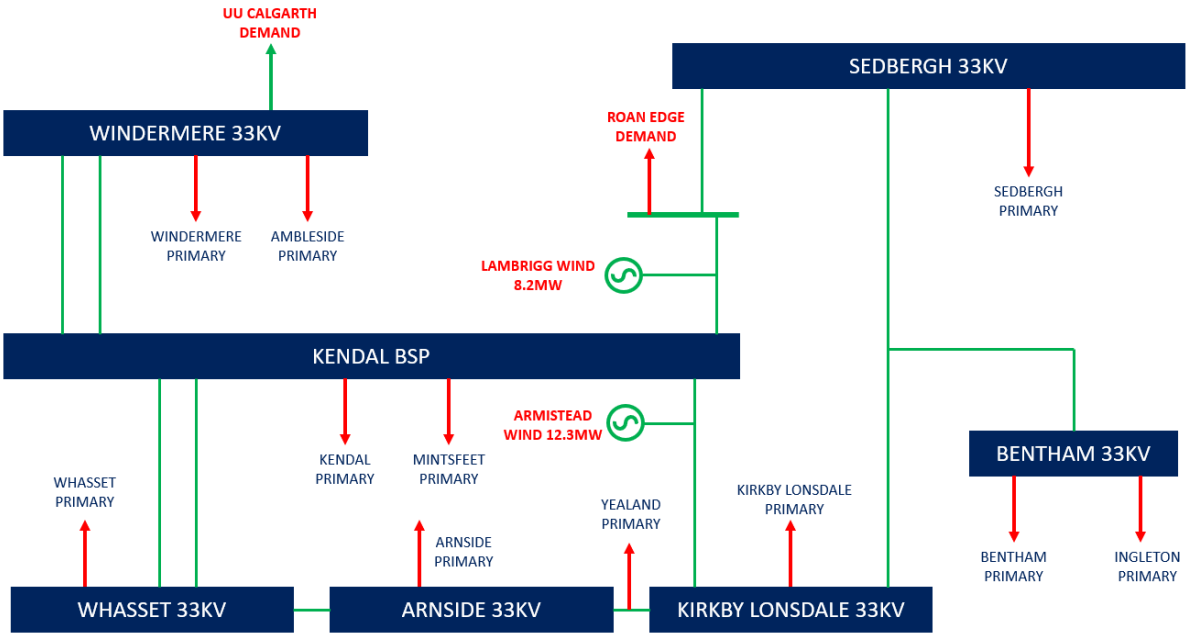


Figure 23: Kendal BSP network



6.3.2 Scenarios and tests

The live network trials will be carried out on a section of the network such as the Harker/Hutton network described above where constraint scenarios are likely to occur.

Realistic constraint scenarios such as high levels of generation causing reverse power flows and large commercial demand such as battery import causing thermal overloads are anticipated to occur more frequently with the uptake of low carbon technologies.

At this point the trading platform will be integrated with the ANM system to allow trades to be carried out between the selected customers. This is the first opportunity to test the system on a live network. Curtailment actions will be taken, real payments will be transacted and the ability for the market to realise the benefits of curtailment trading will be gained.

7 Conclusions and next steps

This report addresses the requirements for the BiTraDER D2 deliverable. Taking into account customer feedback, the project team have developed the high-level trading rules, system architecture and trading platform technical requirements. Over the next six to eight months, we will develop:

- the detailed design for the trading platform,
- the detailed requirements for the system interfaces
- the detailed system architecture design
- the scenarios for the mini trials and simulation trials

We will also conduct further customer engagement and recruitment to ensure we have the right mix of customers for the live network trials.