LEO Local Energy Oxfordshire

February 2022 | Version 1

Minimum Viable System Trials: Compilation Report

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Report Title:	**Minimum Viable System Trials: Compilation Report**
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Version:	2.1	Date:	November 2021
Workpack*:	4 & 7	Deliverable:	D4.19, D7.11, D7.17
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Date:	1: 12/08/2021 & 10/12/2021, 2: 23/09/2021 & 10/12/2021		
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Date:	10/12/2021		

Can be shared (Y/N):	Internally	Y	Externally	Y

Context

The UK Government has legislated to reduce its carbon emissions to net zero by 2050. Meeting this target will require significant decarbonisation and an increased demand upon the electricity network. Traditionally an increase in demand on the network would require network reinforcement. However, technology and the ability to balance demand on the system at different periods provides opportunities for new markets to be created, and new demand to be accommodated through a smarter, secure and more flexible network.

The future energy market offers the opportunity to create a decentralised energy system, supporting local renewable energy sources, and new markets that everyone can benefit from through providing flexibility services. To accommodate this change, Distribution Network Operators (DNOs) are changing to become Distribution System Operators (DSOs).

Project Local Energy Oxfordshire (LEO) is an important step in understanding how new markets can work and improving customer engagement. Project LEO is part funded via the Industrial Strategy Challenge Fund (ISCF) who set up a fund in 2018 of £102.5m for UK industry and research to develop systems that can support the global move to renewable energy called: Prospering From the Energy Revolution (PFER).

Project LEO is one of the most ambitious, wide-ranging, innovative, and holistic smart grid trials ever conducted in the UK. LEO will improve our understanding of how opportunities can be maximised and unlocked from the transition to a smarter, flexible electricity system and how households, businesses and communities can realise the benefits. The increase in small-scale renewables and low-carbon technologies is creating opportunities for consumers to generate and sell electricity, store electricity using batteries, and even for electric vehicles (EVs) to alleviate demand on the electricity system. To ensure the benefits of this are realised, Distribution Network Operators (DNO) like Scottish and Southern Electricity Networks (SSEN) are becoming Distribution System Operators (DSO).

Project LEO seeks to create the conditions that replicate the electricity system of the future to better understand these relationships and grow an evidence base that can inform how we manage the transition to a smarter electricity system. It will inform how DSOs function in the future, show how markets can be unlocked and supported, create new investment models for community engagement, and support the development of a skilled community positioned to thrive and benefit from a smarter, responsive, and flexible electricity network.

Project LEO brings together an exceptional group of stakeholders as Partners to deliver a common goal of creating a sustainable local energy system. This partnership represents the entire energy value chain in a compact and focused consortium and is further enhanced through global leading energy systems research brought by the University of Oxford and Oxford Brookes University consolidating multiple data sources and analysis tools to deliver a model for future local energy system mapping across all energy vectors.

Table of Contents

Executive Summary

This report presents a series of examples from the MVS Programme of trials which has run from October 2020 through to September 2021. The examples are intended to demonstrate how each step of the MVS Programme progressively builds functionality for assets in enabling them to participate in local flexibility markets. It also gives a small snapshot of the type of technical data, analysis and learnings being generated through the MVS and MVS+ trials within Project LEO.

Through the MVS trials, it has become apparent that assets which are not primarily designed to offer flexibility services require much more time and resource than originally thought on asset characterisation and basic enablement for controllability. As a result of this and the delay of market integration platforms, such as the NMF and WSC, the MVS Programme changed into a more structured, asset centric and linear approach than the original MVS trials intended. While this has somewhat restricted the freedom of trials to innovate in an agile way, the framework has encouraged many more trials to be run in quick succession and stimulated a lot of discussion and learnings which have been used in the development of the Full Trials.

The report plots the journey developed within LEO to enable assets to participate in new local flexibility markets. Initially, trials focus on understanding the technical capability of the asset; this is particularly pertinent for types of assets not primarily designed for power flexibility or have little to no familiarity with existing or future flexibility markets. A good example is at Oxfordshire County Library where trials need to be run to establish if (and when) there is potential for demand side response. The next series of MVS steps focus on the ability of an asset (and service provider) to deliver flexibility in response to a service by focussing on three key stages, instruction, dispatch, and delivery, all of which are mostly manual at this point. Going through this process has helped service providers such as the Low Carbon Hub who have a portfolio of assets, understand the operational requirements for market participation, and for the DNO (SSEN) to develop the end-to-end process for flexibility procurement. Finally, the later MVS+ steps focus on improving asset, market, and platform integration by focussing on increasing the level of automation and process flow between the 3 stages delivery. Through these trials, the project can better understand how more efficient market operation can reduce the marginal costs associated with participation and utilisation.

Looking ahead to the Full Trials, the project must continue to strike a balance between time-based targets for quantity of trials run and the iterative build-measure-learn agile approach which allows informed direction from detailed analysis to meet the unforeseen or changing needs of the market, assets, or stakeholders.

Introduction

This report demonstrates that Deliverable *D7.11 – Principle of the MVS has been demonstrated* – and *D7.17 – Prove the principle of MVS+ has been demonstrated* – has been completed. These deliverables requires that *"All available assets have been used in at least 1 MVS(+) trial allowing the project to progress into MVS+ (Trials) stage (Sandford Hydro; EDF Batteries, V2G charge points; Rose Hill PV & Battery; Oxfordshire County Library)"*. This report is also intended as a summary resource for Project LEO's programme of asset-service based trials, known internally as the MVS Programme, which has been employed by the project since September 2020 to the time of writing in November 2021 (project Deliverable *D4.19*). The report consists of a short introduction to the MVS Programme followed by a compilation of trial highlights to help describe the Programme Steps labelled as MVS and MVS+ trials.

MVS Programme

MVS is an acronym of Minimum Viable System, a concept proposed at the start of Project LEO akin to the Lean Start-up concept of a Minimum Viable Product (MVP) which had gained popularity in fast moving, typically digital, sectors. The idea behind an MVP is to build the most basic form of a product that allows a company to test a new hypothesis, adaptation, or business venture in a low-risk, agile, way to establish if demand exists in the market before committing to potentially costly development.

The key difference when translated to the LEO MVS context is the focus on the whole-system aspect rather than a single product. The smart local energy system (SLES) concept being proposed in LEO, driven in part by rapid digitalisation and decentralisation of the energy system, has at its heart a new DSO (Distribution System Operator) flexibility market capable of supporting local energy trading and the transition to net-zero. This SLES requires the local interaction and operation of multiple stakeholders, energy resources, digital platforms, and business models in new ways not previously demonstrated or initially designed for.

Due to the nature of a fast-moving energy transition happening in an ever-increasing digital space, the Lean agile approach seemed well suited for such a project. The approach developed is summarised in the diagram below and can be applied at multiple different levels within the project.

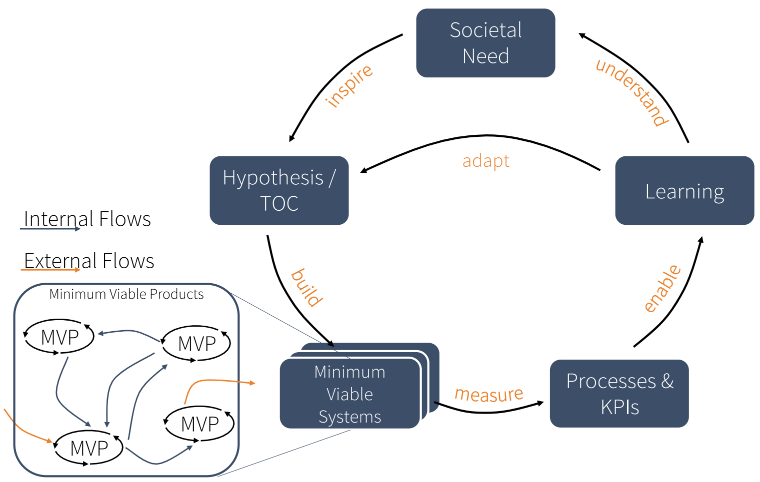


Figure 1: Lean agile approach as proposed within Project LEO for whole system transformation

For the asset-service based trials described herein, the approach can be described as follows. The societal need is the technical delivery of flexibility as per the proposed DSO flexibility market (versus current DNO operations). This need inspires a hypothesis (or Theory of Change) as to how best to deliver flexibility; this process could be a modification to an already established procedure or an entirely new one. Hypotheses are translated into trial objectives which lead to MVS trial(s) being run. Through the collection of data during a trial, processes and KPIs are measured and analysed to enable new learnings to be generated. These learnings can lead to a better understanding of the requirement (which in the extreme case could indicate a false need and therefore the opportunity to stop a particular avenue of exploration) or an adaption of the hypothesis proposed, both of which inform future iterations.

There have been several challenges in implementing this agile approach whereby the learnings of one MVS trial are intended to inform and motivate follow-up trials.

- Firstly, the development of digital platforms such as the NMF (Neutral Market Facilitator) and the WSC (Whole System Coordinator),[1] that are required for the flexibility marketplace to operate as intended, were delayed, meaning manual workarounds or proxy processes had to be used to test the full end-to-end process. This restricted the programme's ability to progress the detailed functional steps on platform interaction.
- Secondly, the delivery of DSO flexibility services was not initially well understood by the Project Consortium, or the available assets were not enabled to deliver such services in an easily controllable way. More effort than initially envisaged to enable these assets made progress appear stymied, despite important learnings being generated as each asset attempted discrete stages of the end-to-end process. These practical experiences fed into the design and modification of the end-to-end process for Trial Period 1 in a series of workshops facilitated by Origami over the summer of 2021.
- Thirdly, the initial effort required to enable the assets, uncertainty of the final process for service delivery, limited personnel resource, and the challenges of assigning responsibility

[1] Further details on the NMF and WSC can be found SSEN's TRANSITION website or in the NMF and WSC briefing.

across multi-organisational teams meant that generally there was lower engagement than anticipated from the Project Consortium to propose new adaptations and hypotheses to test. However, though the completion of discrete MVS tests (such as the commercial MVS[2]) and a series of summer workshops on market participation the level of engagement has been increasing as the project progress towards the 'Smoke Tests' and formal trials.

- Finally, the MVS approach was successfully enriched with milestones and timeframes to encourage more frequent trials and to quantify progress. Although this was convenient and compatible with the external audit of deliverables, this approach made the agile workflow more difficult to achieve when applied to the digital systems and market processes as emphasis was placed on high-cost physical assets.

The MVS Programme was developed to integrate timeframes and milestones required for external auditing with the Project's existing agile approach. This was led by Origami with input from the MVS working group. The MVS Programme is asset centric and sets out a step-by-step progression for individual assets from basic asset operation and understanding, through to automated flexibility delivery within the context of a service. Although the order of steps largely aligns with operation/process maturity, depending on the asset, these do not necessarily need to happen in order (or at all). Steps are labelled with a trial type to indicate the level of maturity of the functionality being demonstrated. In general, MVS trials are understanding and demonstrating an assets capability of delivering flexibility. MVS+ indicates the asset's (and service providers) technical operational process is sufficiently mature enough that it is capable of participating in a real market in response to a service request. The steps as they appear in the MVS Programme are:

Table 1: Description of each step of the MVS Programme and the type of trial it represents (MVS, MVS+, Pre-Trial, Full Trial). p represents an additional step relating to peer-to-peer services.

Step	Description	Trial Type
1	Potential assets that may be used in MVS/MVS+/Pre-trials	N/A
2	Through dispatch of the asset, determine the 11 service parameters for the asset.	MVS
3	Through dispatch of the service, determine service allocation per asset.	MVS
4	A manual dispatch instruction issued to manually start the asset has resulted in the manual starting of the asset.	MVS
5	An automated dispatch instruction (e.g. via a control platform or following a schedule) issued to automatically (or remotely) start the asset has resulted in the automated starting of the asset.	MVS
6	Specific flexibility service test(s) show that the asset can successfully perform the service for the specified length of time (e.g. Technical qualification of asset).	MVS
7	Availability declarations and changes of availability are received by the DSO/market place.	MVS
8	A manual instruction from service buyer triggers a manual dispatch to deliver a service and resulted in the manual delivery of the service.	MVS

[2] Commercial MVS D4 report: Assessment of Declarations, Baselining Methodology and Settlement; October 2021.

9	A manual instruction from service buyer triggers a manual dispatch to deliver a service and resulted in the automatic/remote delivery of the service.	MVS
10	A manual instruction from service buyer triggers an automatic dispatch to deliver a service and resulted in the automatic/remote delivery of the service.	MVS+
12	NMF/WSC availability	N/A
13	For DSO procured services an automatic instruction from service buyer triggers an automatic dispatch to deliver a service and resulted in the automatic/remote delivery of the service.	MVS+
14	For DSO procured services an automatic instruction from service buyer triggers an automatic dispatch to deliver a service from multiple assets and resulted in the automatic/remote delivery of the service for a reduced amount of time within a simulated constraint.	Pre-Trial
15	For DSO procured services an automatic instruction from service buyer triggers an automatic dispatch to deliver a service from multiple assets and resulted in the automatic/remote delivery of the service to a constrained area of the network.	Full Trial
16	Data collection from the asset during dispatch of flexibility service test(s).	MVS, MVS+
17	Data collection from the monitoring of the constraint on the system and to determine whether service was delivered as instructed	MVS, MVS+, Pre-Trial, Full Trial

The diagram below is a visual representation of the MVS Programme and how the various steps are linked. Those that appear below the black line in the diagram tend to be asset focussed and are labelled MVSs, while those above the surface tend to be within the context of a specific flexibility service and are labelled MVS+, Pre-Trial (terminology changed to ‘Smoke Tests’) and Full Trial (terminology changed to Trial Period 1 (2 & 3)).

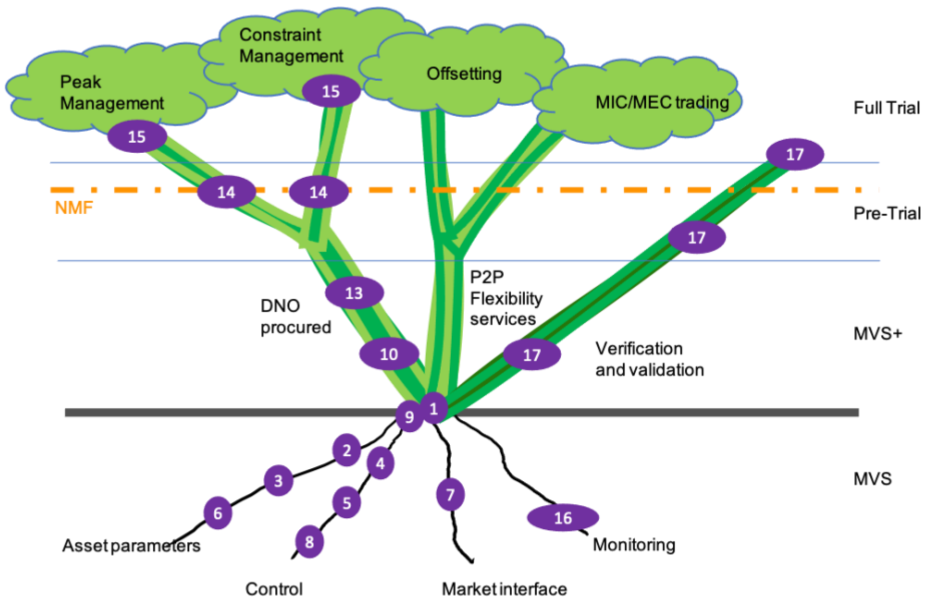


Figure 2: Concept of the MVS Programme produced by Timur Yunusov (Origami), the purple nodules represent the different MVS Programme steps with the green branches highlighting the various types of flexibility service. The yellow dotted line illustrates where the Neutral Market Facilitator (NMF) becomes available for the trails..

In the style of a Gantt Chart, each asset has a schedule by which it is expected to progress through the programme which is monitored internally within the project by the MVS Working Group on a fortnightly basis. The completion of particular steps have been integrated at Project level as deliverables in the Detailed Project Plan (DPP) under the newly created Work Package 7.

The MVS Programme applies the more classic Waterfall Project Management structure to the MVS trials whereby particular steps must be completed (or at least started) as per a pre-planned timeframe. The steps themselves describe the objective of the trial and therefore simplify trial design and leads to similar development work across all assets. The result has been a much higher frequency of trials being run across all assets with a logical progression of asset capability. However, the programme has become very asset centric with less attention on whole system integration or service design that was a focus of early MVS work in the first 18 months of the project. Developing this workflow has been moved to the 'Smoke Test' period that follows the introduction of the NMF platform. Due to limited time and personnel resource, the meeting of specific asset deadlines is prioritised over explicitly capturing and evaluating the learnings to feedback into future system iteration (as per the original agile approach). There is a lot of data and results being generated which are not easily accessible to those not directly involved in the trial, meaning collation of broad learnings for the project is difficult. Attempts to mitigate against this include the MVS Working Group monthly review slides which provide a high level record of key learnings and trial activity, interviews conducted by WP6 which feed into the annual synthesis report and quarterly updates, standalone reports (e.g. the Commercial MVS report mentioned earlier), trial workshops led by Origami, and finally spotlight presentations as part of the monthly project monitoring meetings. It is important for the Full Trials that the correct balance is found between time-based targets and agile feedback loops which will ensure that the system meets the changing/developing needs of the market, assets, and participants.

The Assets

There are currently six energy resources which are part of the MVS Programme:

Sandford Hydro Active Power

Sandford Hydro is a 440 kW community micro-hydro located on the River Thames, south of Oxford, at Sandford-on-Thames. It is managed by the Low Carbon Hub and consists of three Archimedes screws, the speed of which can be adjusted to control the flow of water and therefore active power output of the hydro. Output depends on river conditions and therefore the asset has a high degree of seasonality and weather dependence. There is a possible opportunity to use the river as storage and it is being explored as part of the trials, however, due to leakage over the weir and operating with tight Environment Agency limits, this opportunity is limited. Sandford Hydro is connected to the distribution network at 11 kV through Kennington Primary Substation.

Figure 3: Sandford Hydro

Sandford Hydro Reactive Power

The reactive power output of Sandford Hydro can be adjusted by adding or removing capacitors from the circuit in the hydro's power factor compensation cabinet. This process requires personnel on-site to manually adjust the capacitance of the system. This alters the plant's power factor. Reactive power services are being investigated as a possible additional revenue stream at the hydro that does not require adjustments to river flow during delivery. Such reactive power services may be beneficial to the DNO in managing voltage on the network.

Rose Hill Primary School Battery

Figure 4: Rose Hill Battery being installed

Rose Hill Battery is a 50 kWh, 15 kW Offgrid Energy GridtoGo INGENIUM battery installation at Rose Hill Primary School, owned and operated by the Low Carbon Hub and installed in 2020. The battery is co-located with 28 kW of rooftop solar PV, also managed by the Low Carbon Hub. It is connected at 400 V through the Nowell Road secondary substation and the Rose Hill primary substation.

Oxfordshire County Library

The Oxfordshire County Library (more commonly known as the Westgate Library) is a Library owned by Oxfordshire County Council located at the entrance to the Westgate Shopping Centre) in central Oxford. Flexibility is provided through demand side response (DSR) from the Heating, Ventilation and Air Conditioning (HVAC) system; the majority of HVAC load is from the 140 kWth chiller. As a DSR resource, Oxfordshire County Library is not a dedicated energy asset with no prior experience delivering flexibility services. As the flexibility is provided through cooling, the capacity of flexibility is highly weather dependent and seasonal.

EDF Domestic Batteries

To test aggregation of multiple assets, EDF have a portfolio of four Powervault residential batteries installed at domestic customer properties. The customers have existing agreements in place with EDF for operation (through EDF Powershift platform) within national balancing markets. The four batteries available within LEO each have 8 kWh with 3.6 kW charge/discharge capacity. The batteries are installed at low voltage behind-the-meter at domestic customer properties in various locations across SSEN's Oxfordshire network.

Nuvve V2G Chargers

Nuvve are an aggregator specialising in providing electric vehicle smart charging and vehicle-to grid (V2G) services. As part of LEO, Nuvve have facilitated the installation of V2G charging points at multiple sites across Oxfordshire, including at LEO partner sites at Oxford Brookes University and Oxford County Council.

Demonstrating the principle of MVS

The coloured cells in the table below summarise which assets have completed at least one trial within each of the steps labelled ‘MVS’ or ‘MVS+’, see Table 1. The blue cells represent the examples presented in the rest of this report to give a small snapshot of the type of technical data, analysis and learnings being generated through the MVS trials within Project LEO.

Table 2: Coloured cells indicate that an asset has completed at least one MVS trial within each of the 10 MVS Programme Steps labelled ‘MVS’ and ‘MVS+’. The blue cells represent asset examples presented in this report.

Step	**Description**	Sandford Hydro Active	Sandford Hydro Reactive	Rose Hill Battery	Oxfordshire County Library	EDF Domestic Batteries	Nuvve Chargers
2	Determine Asset Parameters						
3	Determine Service Parameters						
4	Manual Dispatch, Manual Delivery						
5	Automatic Dispatch, Automatic Delivery						
6	Specific Flexibility Service Test						
7	Availability Declarations						
8	Manual Instruction, Manual Dispatch, Manual Delivery						
9	Manual Instruction, Manual Dispatch, Automatic Delivery						
10	Manual Instruction, Automatic Dispatch, Automatic Delivery						
13	Automatic Instruction, Automatic Dispatch, Automatic Delivery						
16	Asset Data Collection						
17	Network Data Collection						

Step 2 – Determine Asset Parameters

Step 2 of the MVS Programme – Determine Asset Parameters – is intended to help characterise the technical operation of the asset through actual dispatch. While this might be trivial or unnecessary for many dedicated flexibility devices such as batteries with well-characterised specifications, it can be extremely valuable for assets, such as building DSR, where the flexibility is unknown or untested. This step (along with Step 3) also serves as a proxy for technical qualification which might be a prerequisite for real market participation. Assets may have to repeat this step as uncertain assets with seasonality or weather dependence may require characterising at different times of the year.

Assets are expected to report fixed figures (if possible) or method for determining such a figure in the case of a variable asset (such as DSR) against 11 asset parameters which are summarised in Table 3 below.

Table 3: Asset parameter definitions

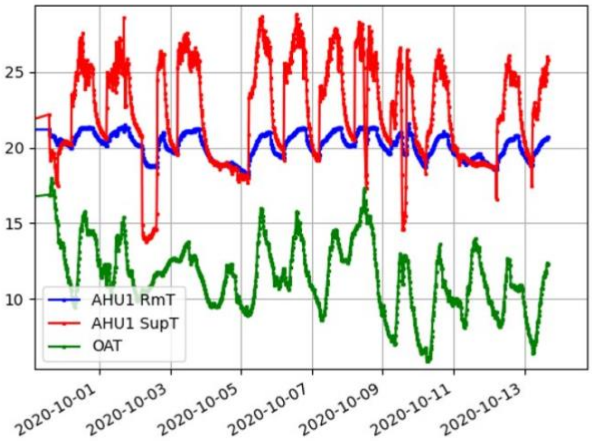
Asset Parameter	Description
Notice period	The amount of time prior to service delivery the asset must be informed of the need to deliver.
Ramp up time/rate	The time required for the asset to go from point of dispatch (business-as-usual operation) to flexibility delivery target. Might be reported as a rate per MW or total time.
Minimum amount of flexibility	The lowest power that corresponds to the maximum duration of flexibility delivery.
Maximum amount of flexibility	The maximum power that corresponds to the shortest duration of flexibility delivery.
Minimum duration of flexibility delivery	The shortest duration of flexibility that can be delivered when operating at maximum power.
Maximum duration of flexibility delivery	The longest duration of flexibility that can be delivered when operation at the minimum power.
Ramp down time	The time required for the asset to go from a 'flexibility delivery level' back to business-as-usual operation.
Minimum time before next use	The minimum amount of time required between service windows assuming full flexibility delivery.
Number of cycles (per day)	How many times within a 24-hour period the asset could respond to a flexibility service assuming minimum duration of flexibility delivery and minimum time between uses.
Metering data collected	What quantities are metered? E.g., active power, voltage, 3-ph current etc.
Metering data collection frequency	What is the frequency at which data are recorded (might be different to acquisition rate or upload frequency).

Oxfordshire County Library – MVS A3.2.1

The trials and analysis presented in this section were conducted by Avinash Vijay (University of Oxford) and the estates management team at Oxfordshire County Council.

Early MVS trials run at the Oxfordshire County Library have been focussed on basic quantification of available flexibility from the HVAC system. Unlike a battery, this potential DSR asset was not specifically designed to provide flexibility services and has not been used in this way before. To establish the potential flexibility of the building, a basic thermal model of the building is used. Trials involving temperature setpoint changes are used to determine the empirical thermal parameters. Although there is no electrical heating in the building currently, flexibility is expected to come from the electrical chiller in the summer months; trials with the heating system in the winter can still be used for thermal modelling to inform flexibility capacity in the summer months (or if electrical heating was implemented). Further details of the thermal modelling approach are detailed in the Project LEO MVS Sackler Library Technical Report.

To understand how the building's internal temperature responds to external or BMS (Building Management System) input, thermal building data were analysed over a period of 4 months between September 2020 and January 2021 where the HVAC system of the building was operating to a normal daily schedule correlated with the opening times of the building (Figure 5 *top*). The accuracy of the basic thermal model was tested against measured data as seen in (Figure 5 *bottom*).



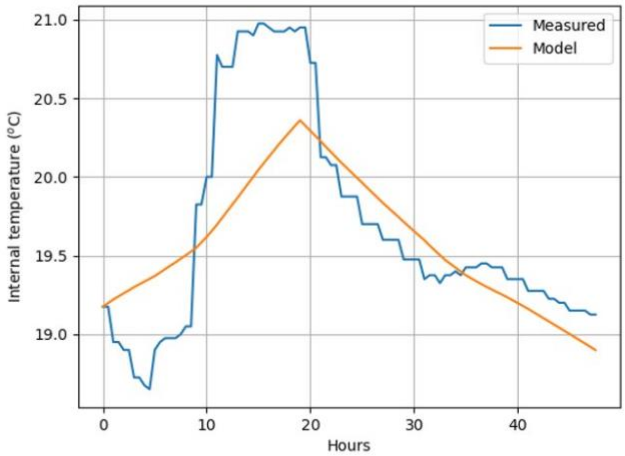


Figure 5: (top) Example BMS data for the Oxfordshire County Library including room temperature (blue), supplied air temperature (red) and outside air temperature (green); (bottom) Resulting thermal modelling of internal temperature: actual measured temperature (blue) and modelled temperature (orange).

The thermal modelling can then be used to model the expected impact of using the HVAC system for flexibility. In the example shown below in Figure 6, turn-up flexibility is analysed (increasing the electrical demand of the HVAC system). The black lines show the expected impact on the internal temperature because of either an increase in heating demand (positive kW) or an increase in cooling demand (negative kW). The horizontal lines indicate typical comfort limits for the library which have been guided by building management standards given the library's typical users. The point of intersection between a black line and a red line indicates the length of time at which that amount of flexibility can be delivered before a comfort limit is breached.

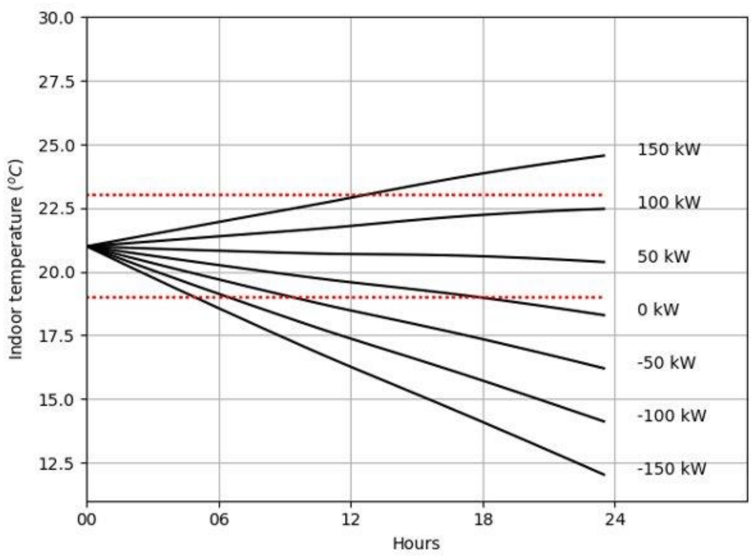


Figure 6: Assessing the impact of HVAC turn-up flexibility on internal building temperature at the Oxfordshire County Library (Oxfordshire County Library). Black lines represent the change in external temperature from an increase in heating power (for positive (+) kW) or an increase in cooling power (negative (-) kW). The red horizontal lines show typical comfort limits which are 19 and 23 °C.

This analysis can be applied across the year for a particular daily flexibility window to determine the amount of flexibility possible with the constraint that internal temperatures must stay within the comfort limits. The results are shown in Figure 7 for turn-up (left) and turn-down (right) flexibility. Note that the heating flexibility is theoretical if electrical heating was installed; the library currently has gas boilers and therefore cannot provide electrical flexibility through heating.

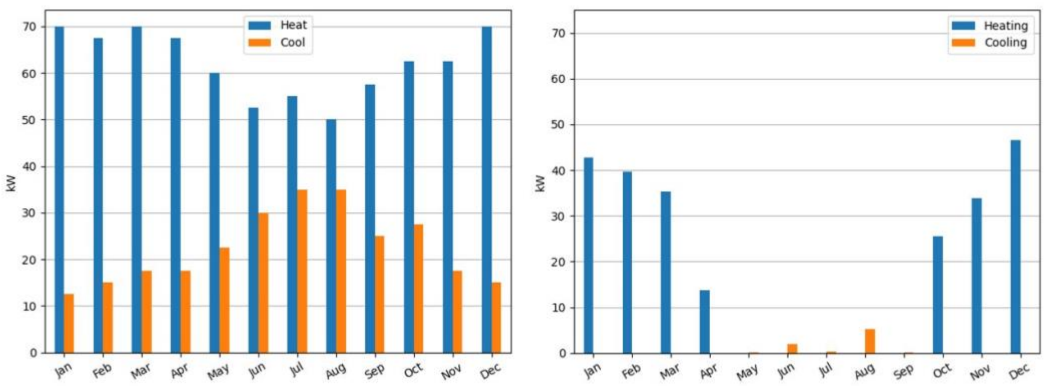


Figure 7: Monthly maximum HVAC flexibility capacity for theoretical heating and actual cooling at the Oxfordshire County Library. (left) Turn-up flexibility and (right) turn-down flexibility.

The turn-down flexibility is much more restricted as the scenario requires that heating or cooling would have been active during the service window if flexibility was not instructed (such that it can be switched off). Current building management at the Oxfordshire County Library dictates that the chiller which provides cooling is only switched on for the summer months, around May/June through to August/September, thus its use is not necessarily governed by weather conditions all year round.

Step 3 – Determine Service Parameters

Step 3 of the MVS Programme – Determine Service Parameters – provides an opportunity to test through asset dispatch, the expected service allocation of the asset. Project LEO and TRANSITION are testing 7 different services within 2 main categories. DSO Procured Services include: Sustain Peak Management (active power), Sustain Export Peak Management (active power), Secure DSO Constraint Management (pre-fault), Dynamic DSO Constraint Management (post-fault), while the peer-to-peer DSO Enabled Services include: Exceeding Maximum Export Capacity, Exceeding Maximum Import Capacity and Offsetting. Each service has service parameters which an asset must meet if it is to take part and the purpose of this step is to test these technical requirements if unknown for a particular asset. Further detailed analysis of the potential for assets to take part in different services can be found in the Project LEO report: Value Chain for Flexibility Providers.

Table 3: Summary of Flexibility Services to be tested in Project LEO and TRANSITION

Category	Service	Description	Auction Period	Delivery Notice	Delivery Duration	Minimum Capacity
DSO	Sustain -Peak Management (SPM)	A Flexibility Service that delivers Flexibility to address a forecasted need to prevent a critical asset (such as transformer) becoming overloaded due to excess demand	Months to Years	Month Ahead to Day Ahead	[2 hours]	1kW
	Sustain – Export Peak Management (SEPM)	A Flexibility Service that delivers Flexibility to address a forecasted need to prevent a critical asset (such as transformer) becoming overloaded due to excess generation	Months to Years	Month Ahead to Day Ahead	[2 hours]	1kW
	Secure - DSO Constraint Management (pre-fault) (SDCM)	A Flexibility Service that delivers Flexibility to address an emerging issue that could result in an unplanned outage or an event if not addressed.	DNO-dependant	Week Ahead	[2 hours]	1kW
	Dynamic - DSO Constraint Management (post-fault) (DDCM)	A Flexibility Service that delivers Flexibility after an unplanned outage or fault has occurred	DNO-dependant	120 to 15 mins	Up to 8 hours	50kW (total across all DERs
P2P	Exceeding Maximum Export Capacity (EMEC)	Two Market Actors on a network with an unconstraint path between each other trade a portion of their export capacity so one can increase its existing export for an agreed period without affecting the network	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
	Exceeding Maximum Import Capacity (EMIC)	Two Market Actors supplied by the same substation trade a portion of their import capacity so one can increase its existing import for an agreed period without affecting the network	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
	Offsetting (OFFST)	Two Market Actors in a constrained area working together so one increases its demand (or generation) before another increases its generation (or demand) by the same amount, with appropriate fail-safe mechanisms	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC

Rose Hill Battery – MVS A2.7.3 (14/12/2020)

The trial and data collection presented in this section were conducted by Harry Orchard (LCH).

The objective of this MVS trial was to test the process of using Rose Hill Battery to deliver a pseudo flexibility service with an automated dispatch and delivery of the asset. At the same time, the trial was used to learn more about the how the battery responds to remote signals.

The required service was the delivery of 15 kW of active power for the period 14/12/2020 14:00 – 15:00. The battery was scheduled to deliver 16 kW to ensure the required power was met. Figure 8 shows the discharge power profile and corresponding state of charge (SOC) for Rose Hill Battery during the service event. As expected, the battery is clearly capable of delivering the 15 kW service with stable output for the scheduled service time. The state of charge drops by around 40% indicating this output could be sustained for a maximum of 2.5 hrs as expected.

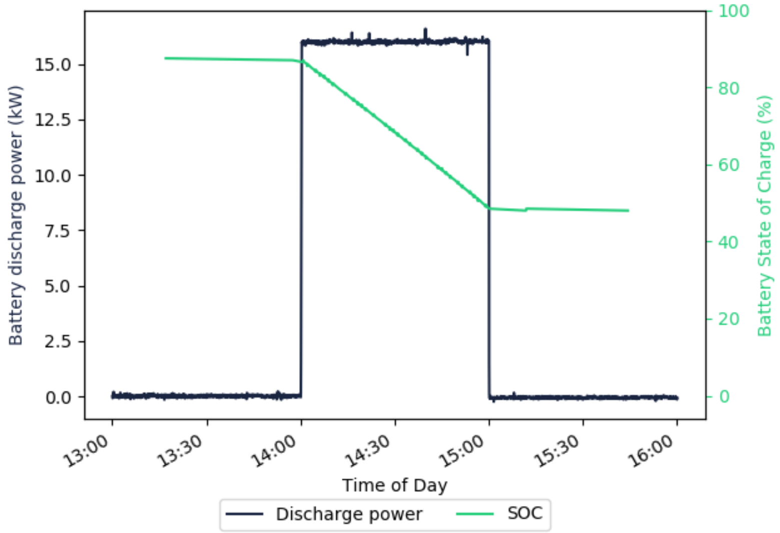


Figure 8: Rose Hill Battery discharge power profile measured at 3-second resolution for MVS A2.7.3 which required 15 kW export for 1 hour between 14:00-15:00 on 14/14/2020.

Figure 9 shows a close-up of the ramp-up and ramp-down times of the battery for the service above. Having run the trial, it is possible to observe the battery has an 18-second ramp up time to 16 kW which started 5 seconds after the scheduled 14:00 start and a subsequent 6-second ramp down time back to 0 which started 2 seconds after the scheduled 15:00 end. Such trials enable new assets or previously untested assets to identify which services an asset is suitable for based on measured performance before being exposed to real market conditions and potential penalties.

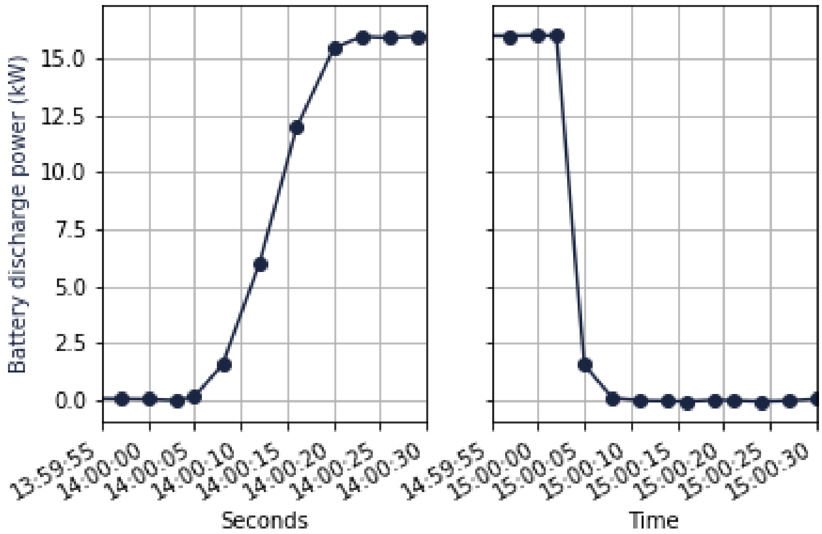


Figure 9: Rose Hill Battery discharge power ramp-up and ramp-down during MVS A2.7.3.

Step 4 – Manual Dispatch, Manual Delivery

Step 4 of the MVS Programme – Manual Dispatch, Manual Delivery – is the first step where more than one end-to-end service stage are tested together. Dispatch is the process performed by the service provider to command the asset to begin delivering; delivery is the physical output of flexibility by the asset. At this point of the programme, both processes are performed manually. The objective of this step is to ensure the asset responds to the service providers dispatch command and delivers as expected.

Oxfordshire County Library – MVS A3.3.1 (02/03/21)

The trials and analysis presented in this section were conducted by Avinash Vijay (University of Oxford) and the estates management team at Oxfordshire County Council.

The objective of the trial described below was to make a manual change in the temperature setpoint on the BMS of the Oxfordshire County Library to verify that this would lead to a physical change in HVAC operation and thus provide a flexibility service. Due to the time of year, this was performed as a turn-down event of the building's heating. While this is fuelled by natural gas and therefore does not result in a change in electrical demand, it provides valuable learnings in understanding how setpoint changes within the BMS software control HVAC operation, verifying modelling results discussed above. As this was the first time the building has been trialled for the delivery of a flexibility service, OCC's estate team and University of Oxford researchers were on-site to manually control the delivery.

Temporary temperature sensors were located around the main library atrium to assess how a service might affect user comfort throughout the building. Sensors labelled '1' and '2' were placed on the second floor in the corners of the room with sensors '3' and '4' being placed in the centre of the atrium on the first floor. A manual change in temperature setpoint from 22 °C to 21 °C for all 4 AHU that serve the main atrium was made at 8:30 am (it was hoped that this would reduce the heating load of the building). The temperature setpoints were reverted to 22 °C at 12:00 noon.

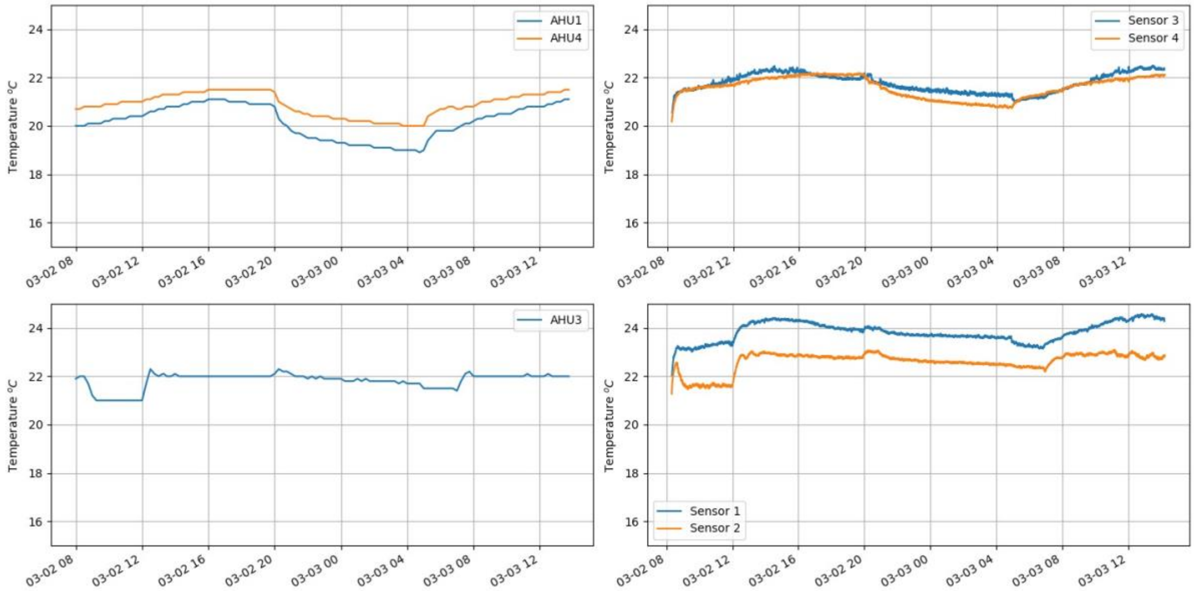


Figure 10: Oxfordshire County Library internal temperature sensor readings. Sensors labelled 'AHU' are integrated BMS sensors the AHU responds to, while those labelled 'Sensor' (1 through 4) are temporary sensors installed for the trial.

The thermal data collected from the various sensors during the trial are shown in Figure 10. There is evidence that a change in HVAC load occurred, but the trial provided some unexpected results and learnings which then instigated further investigation in future trials.

The manual delivery of a service can be observed in the data for AHU3 (bottom left) but not in AHU1 or 4. This is likely because AHU1 and 4 were measuring a temperature below both the starting 22 °C and new 21 °C setpoints and therefore did not respond to the changes. Whereas AHU 3 was operating at 22 °C and reduced heating load to maintain the lower setpoint temperature of 21 °C.

The effect of the service was picked up by sensors 1 and 2 (located near the output vent of AHU3) but not by sensors 3 and 4 (in the centre of the room away from any AHU outputs). The absolute difference in temperature between all sensors is larger than the measured variation in sensor accuracy between the sensors. This difference is representative of spatial differences in temperature throughout the building and suggest changes in AHU output are felt faster locally but likely take a long time to equilibrate throughout the whole space.

These results have implications for both the technical operation of the flexibility and user comfort. Firstly, the potential for local BMS feedback (if sensors are located too near to output vents) must be accounted for. Secondly, setpoint changes must be relative to local AHU conditions rather than the being same across all AHUs if a collective response is required, and thirdly, the capacity of the building will differ if modelling the thermal dynamics of the whole space or just the local AHU area.

Finally, for user comfort, library users sat close to an AHU output might be more effected by the change than elsewhere in the building leading to complaints.

Step 5 – Automatic Dispatch, Automatic Delivery

Step 5 of the MVS Programme – Automatic Dispatch, Automatic Delivery – advances step 4 by testing the automation of the previously manual dispatch and delivery. The automated aspect is intended to remove the need for a person to be present at the asset to ensure delivery. Automatic dispatch can be achieved through a digital control platform or through scheduled control, and this should result in the automatic delivery of the expected flexibility by the asset.

EDF Domestic Batteries – MVS A4.1.1 (22/12/20)

The trials and analysis presented in this section were conducted by Roberto Moreira (EDF).

The domestic batteries which EDF operate remotely on behalf of the customer are examples of assets which are already delivering flexibility services in other markets and require less characterisation and enablement than the previous assets. Manual operation is not an option here and therefore, they are able to jump immediately to step 5 and demonstrate automatic dispatch and delivery. In fact, this trial was used to test steps 5 – 10, 16 and 17 simultaneously.

The objective of this trial was to better understand how a portfolio of assets can be automatically dispatched in response to a service request, collectively delivering the required service for the DNO. There are several stakeholders involved in this service delivery, EDF as the service provider, EDF's Powershift platform as the aggregator, PowerVault as battery owner and supplier responsible for executing the service request and finally the customer whose site the battery is located on and has signed contracts with the other parties for the service. The scheduled service was for a 60 min charging action of 14.4 kW followed by a 30-minute discharge at 14.4 kW.

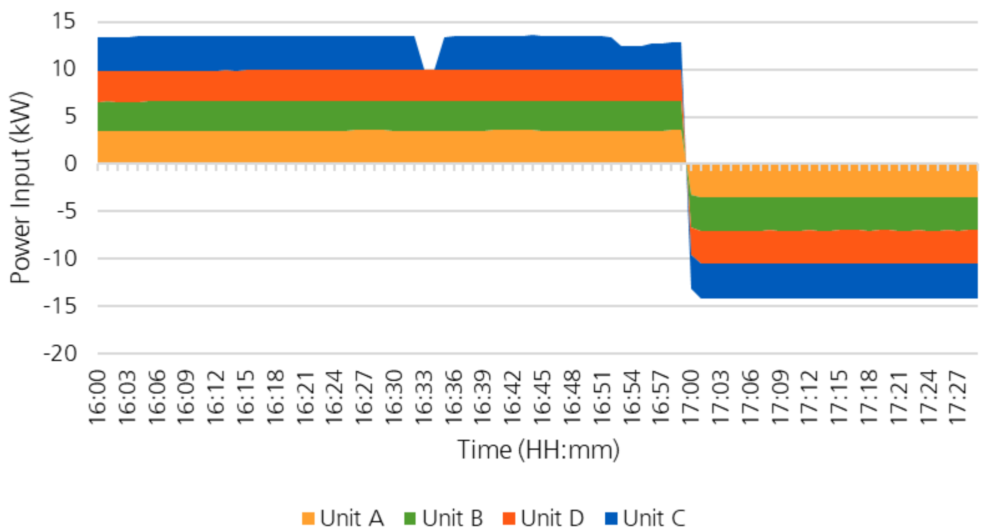


Figure 11: EDF's aggregation of four domestic 3.6 kW batteries (Units A-D) during MVS A4.1.1 trial

The four batteries were dispatched simultaneously but interestingly during the trial, one of the battery units (Unit C - in blue) rebooted after 30 minutes of operation, with a 2-minute interruption, and later showed unstable power input as it reached high SOC. This is a demonstration of how aggregation through diversity de-risks market participation for the asset owner and simplifies market coordination for the DSO. If taken individually, Unit C had a 100% drop-out for that period, reducing the delivered service, potentially being liable for penalties due to under-delivery/a failure to deliver. The relative effect on the aggregated service is much smaller and could be compensated for in real-time from other participating assets given that capability exists.

Step 6 – Specific Flexibility Service Test

Step 6 of the MVS Programme – Specific Flexibility Service Test – is intended to test the asset within the context of a specific flexibility service request. Rather than being unconstrained as to how and when the asset delivers flexibility as per previous steps, importance is now placed on the asset's response to a pre-agreed service i.e., delivery of a certain power for a certain length of time.

Rose Hill Battery – MVS A2.15.1 (31/03/21)

The trial and data collection presented in this section were conducted by Harry Orchard (LCH).

This trial was initially intended to demonstrate the coordinated response of two assets, Rose Hill Battery and Sandford Hydro, however, due to a technical fault at Sandford Hydro, only Rose Hill Battery took part. As described above, delivery is in response to a specific flexibility request. This request was made by the DSO, advertised through the Piclo market platform through which the LCH placed a bid to provide the service, finally receiving a dispatch instruction via text from the DSO.

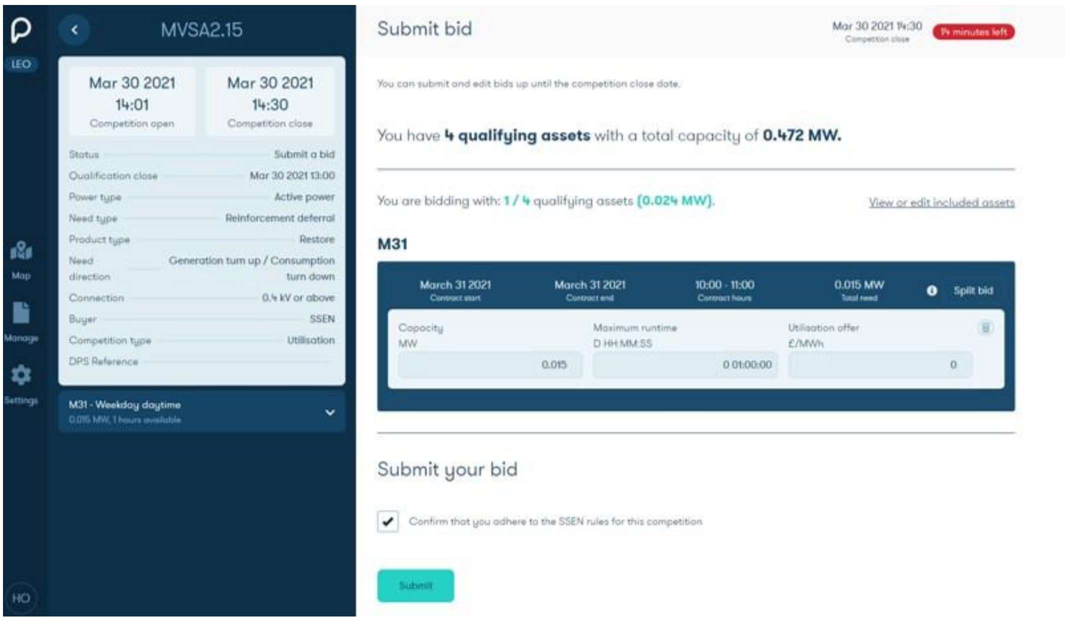


Figure 12: Example of bid submission by a service provider (LCH) for a specific flexibility service.

Figure 12 shows a screenshot of a specific flexibility request as it appears on the Piclo platform when the service provider, in this case the LCH, makes a bid to provide part of the service. As can be seen from the left of the screenshot, the service was an active power restore service requiring 15 kW of generation turn-up/consumption turn-down for 1 hour on a weekday. From the right of the screenshot, the LCH is entering a bid to provide the full 15 kW service for the duration of 1 hour at £0/MWh utilisation price.

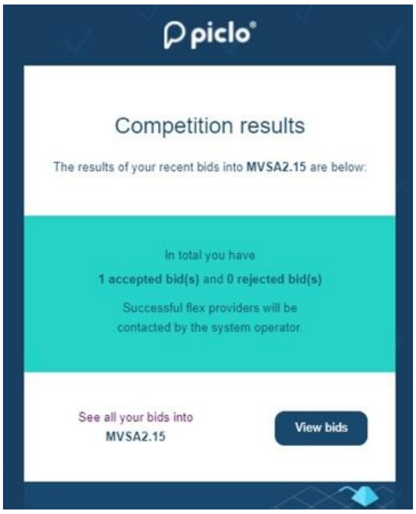


Figure 13: Piclo competition notification of successful bids

Figure 13 is an example of the notification received by the service provider of any successful bids for the service competition. This is followed by the instruction to dispatch sent by the DSO to the service provider shortly before the service window confirming that the service should be delivered.

Figure 14: Instruction to dispatch a specific service from the DSO to service provider prior to the service delivery window.

Finally, Figure 15 shows the resulting flexibility delivery from Rose Hill Battery (dark blue trace) in response to the specific flexibility request. As is clearly visible, the battery discharged at a constant power for the full 1-hour period at (or just exceeding) the 15 kW requested active power service.

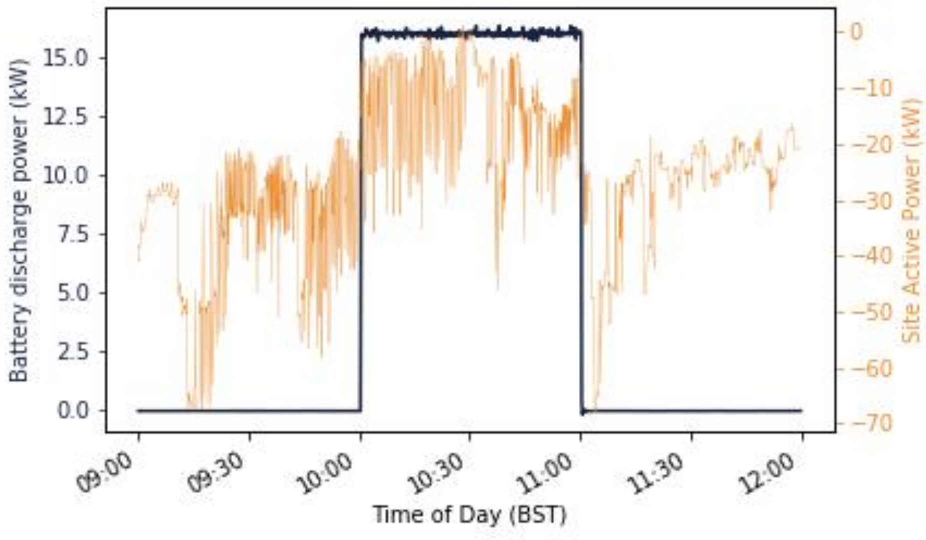


Figure 15: Rose Hill Battery discharge power (dark blue) and site active power (orange) in response to a specific flexibility request requiring a generation turn-up of 15 kW for 1 hour between 10:00 and 11:00 am.

Other insights from the trial included the shape of the site active power (orange trace – negative indicates overall site consumption) which is highly variable in the hours before and after the service window due to electricity use as part of regular site activity and the effects of the on-site PV generation. While there is visible shift in the site's monitoring, the variability in usage elsewhere on the site makes it harder to determine the exact magnitude of service provided by the battery from site metering alone.

Step 7 – Availability Declarations

Step 7 of the MVS Programme – Availability Declarations – is the first step where interactions between different elements of the market are tested. This step tests how asset availability prior to an event can be communicated to the DSO or market platform and updated should this availability change. The exact nature of this process is expected to evolve over the course of Project LEO and will likely differ depending on the platform.

Sandford Hydro – MVS A2.13.1 (31/03/21)

The trial and data collection presented in this section were conducted by Harry Orchard (LCH).

As mentioned above, the Rose Hill trial, MVS A2.15.1, was aligned with MVS A2.13.1 at Sandford Hydro to test the coordinated dispatch of two assets owned by a single service provider. However, due to a technical fault, it was not possible to use Sandford Hydro for flexibility during that trial. As this was discovered after the competition had been successfully entered, a change in availability was needed on the Piclo platform to notify of the asset's change in availability. This provided the opportunity to test the new Piclo dashboard functionality for declaring availability; this was previously done through submission of an Excel document.

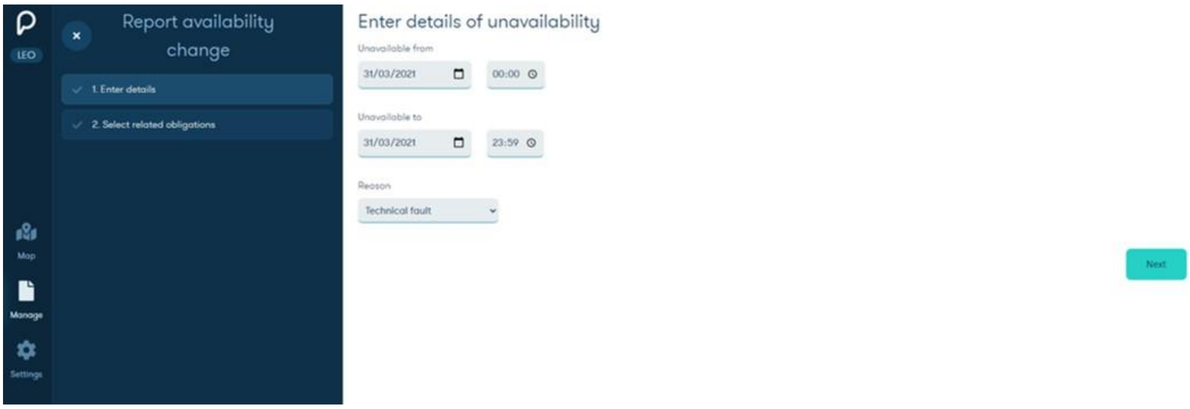


Figure 16: First step in notifying the market through the Piclo web interface of a change in availability – recording details of asset unavailability.

Figure 16 and Figure 17 provide screenshots of the Piclo web interface for declaring unavailability to the market. Firstly, details of the unavailability must be declared including the reason for it (Figure 16). Secondly, the specific service windows that are affected need to be selected (Figure 17).

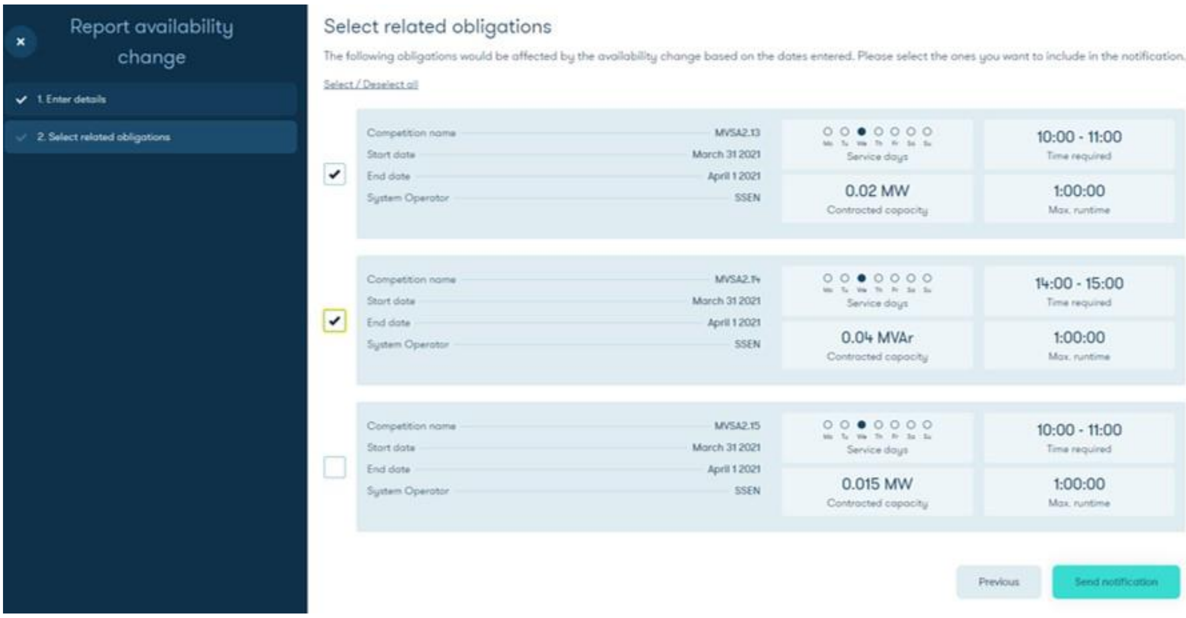


Figure 17: Step 2 of reporting availability change to the market through the Piclo web interface - notifying which specific competitions this relates to.

Step 8 – Manual Instruction, Manual Dispatch, Manual Delivery

Step 8 of the MVS Programme – Manual Instruction, Manual Dispatch, Manual Delivery – adds the additional procedure step of DSO instruction. This is now trialling three consecutive interactions within the context of a flexibility service. Firstly, the DSO sends a manual instruction requesting delivery of a (pre-agreed) flexibility service (including the defined shift in power and the length of service) which is received by the service provider. This is then manually translated into a manual dispatch instruction (as per step 4) which is ‘sent’ to the asset, and which finally results in the manual delivery of a service by the asset.

Sandford Hydro Reactive – MVS A2.6.2 (02/12/20)

The trial and data collection presented in this section were conducted by Harry Orchard (LCH).

The objective of MVS A2.6.2 was to test the ability of Sandford Hydro to provide a reactive power flexibility service. The reactive power at Sandford Hydro can be controlled by changing the number of capacitors connected to the hydro’s power factor compensation circuit, this is a manual process and is included in this section as demonstration of Step 8 of the MVS Programme which involves the end-to-end process from manual instruction through to manual delivery.

Figure 18: MVS A2.6.2 (incorrectly labelled on the Piclo platform as MVSA2.4.1)

A competition was set up on the Piclo platform for 10 kVAr as seen in Figure 18 above for which Sandford Hydro submitted a bid to provide the requested flexibility. The manual dispatch instruction (also seen in the example provided for Step 6) was in the form of a text message sent by SSEN to the LCH as evidenced in Figure 19. This text message is a proxy for the automated notification that will form part of the neutral market facilitator platform (NMF) being developed for the Full Trials. The service instruction was for +10 kVAr for 1 hour between 13:00 and 14:00 on 02/12/2020.

Figure 19: Manual instruction from the DSO to service provider in the form of a text message, used as a proxy for the automated notification service which will be part of the NMF platform.

The DSO instruction was received by LCH and translated into a manual dispatch, manual delivery action which involved staff from the LCH being on-site at Sandford Hydro to disconnect one capacitor from the power factor compensation capacitor bank. This resulted in an increase in reactive power as evidenced from the blue trace in Figure 20. The increase in reactive power was on the order of 50 kVAr, more than the 10 kVAr requested as part of the service. Active power (green trace) remained constant throughout the trial while the power factor (dark grey trace) remained well within the allowable range.

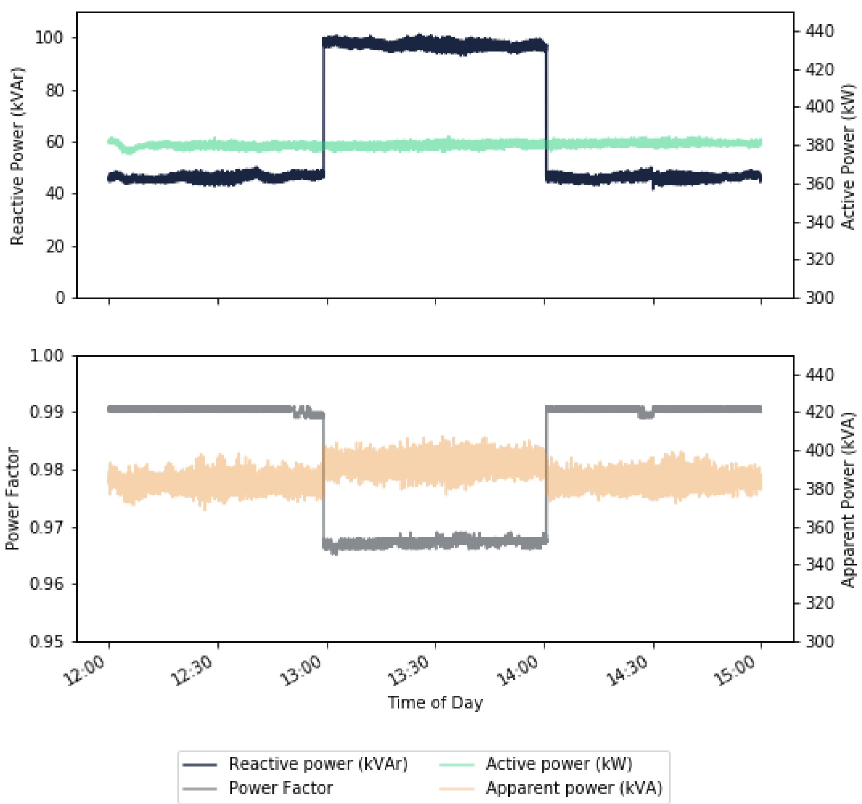


Figure 20: Sandford Hydro power characteristics during MVS A2.6.2

For the particular river conditions present during this trial, the minimum amount of reactive power is 50 kVAr. Due to the discrete nature of how power factor is controlled, this cannot be varied without adjusting active power output as well. There is also a staff cost which much be considered with this service as automation of power factor control is not currently possible.

Further trials are ongoing to determine repeatability, river dependence and the business case for providing such a service.

Step 9 – Manual Instruction, Manual Dispatch, Automatic Delivery

Step 9 of the MVS Programme – Manual Instruction, manual dispatch, automatic delivery – corresponds to a similar progression as between step 4 and step 5, where the resulting service, which has been received from a DSO instruction, is automatically or remotely delivered (e.g., a person does not need to be next to the asset at time of delivery to manually adjust its output).

Sandford Hydro Active – MVS A2.16.2 (18/04/21)

The trial and data collection presented in this section were conducted by Harry Orchard (LCH).

Unlike with the reactive power service described above, LCH can vary the speed of the screws, and therefore the active power output, of Sandford Hydro remotely. This does not require a staff member to be on-site during delivery and is thus classed as an automatic delivery for the MVS trials. The objective of the MVS A2.16.2, in addition to demonstrating Step 9, was to test the ability of Sandford Hydro to provide active power flexibility by storing water upstream, quantifying the energy loss through this storage technique for the river conditions experienced at this time of year (mid-spring).

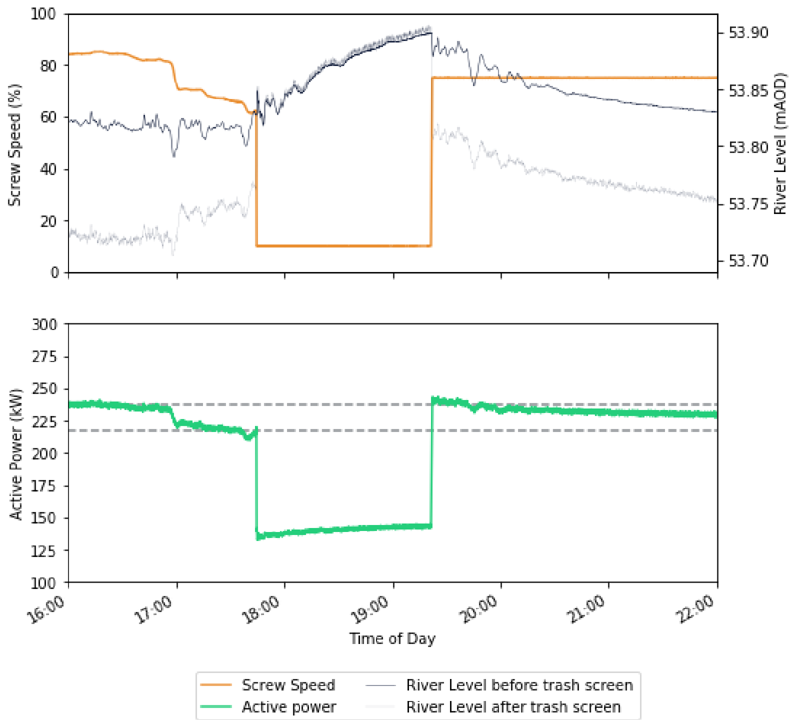


Figure 21: Sandford Hydro operational data during MVS A2.16.2 active power flexibility trial. Top: screw speed (orange) and river level (blue) in meters above ordnance datum (mAOD); Bottom: active power generation.

The service was scheduled as a 10 kW active power generation turn-up event for 1 hour on 18/04/2021; delivery was dispatched and delivered remotely by a LCH contractor at 19:21. Figure 21 shows the operational data for the hydro during the event. There was a period of 95 minutes from 17:45 where one of the screws was slowed to 10% (orange line in top graph) to increase the upper river level to above 53.90 mAOD (dark blue line). As part of the trial, a noticeable drop in river level before and after the trash screen was observed, the effect of which would be investigated in future trials. After the storage period, the speed of the variable screw was increased above that of the pre-storage period to allow a greater flow of water through the hydro, this continued until the river level returned to the equilibrium level.

The bottom graph shows the impact on the active power generation. Prior to the storage period, the hydro was generating on average 217 kW for the period 17:15 – 17:45. During the delivery window, the hydro generated at an average power of 238 kW. This is equivalent to a flex of 21 kW (21 kWh of energy in the 1-hour window). However, during the storage phase between 17:45-19:21, generation dropped to an average of 141 kW, a drop of 76 kW (equivalent to 120 kWh). This significant decrease in the hydro's energy output over the charging discharging cycle indicates a lossy storage system which will have an impact on standard retail revenue. Further analysis is needed to understand how this stacks up against the available revenue from the flexibility market and therefore the hydro's willingness to accept bid offer.

Step 10 – Manual Instruction, Automatic Dispatch, Automatic Delivery

Step 10 of the MVS Programme is the first step labelled as an MVS+. It represents a significant advancement in the ability of a service provider to control their assets at the dispatch stage. In previous steps, an asset was dispatched manually meaning a person was required to take an action to dispatch at the time of delivery. Automatic dispatch implies a degree of automation or scheduling of this step has been achieved that makes it possible to decouple the timing of dispatch from delivery. Scheduling should remove potential limitations imposed by personnel working patterns or in the case of full automation (where the instruction is entirely processed without manual intervention) the cost of personnel time.

Oxfordshire County Library – MVSA3.5.1 (24/09/2021)

The trial and data collection and analysis presented in this section were led by Filiberto Fele (University of Oxford) and made possible by Anitha Sampath, Kunal Prasad and Inga Doherty (Oxfordshire County Council).

In our experience thus far, it is very common in commercial buildings that the BMS that operates the HVAC systems is not setup or designed in such a way for users or building managers to easily respond to flexibility requests, especially in an automated way. In general, these fall into a few categories:

- Firstly, outdated BMS software: BMS software tends to be 'traditional' physical software which requires a new purchase and physical site visits to update, rather than the more recent Software as a Service (SaaS) model. This means many BMSs haven't been updated for many years, can be bespoke for a specific building, and require being on-site to make changes.

- Secondly, connectivity. The ability to remotely access BMS software is often limited. This can be a result of outdated software and hardware. Also, access can be limited due to security concerns, be that directly related to building control, or as a product of wider IT network security. Again, this can lead to on-site working being necessary.
- Thirdly, external BMS contractors. It is common for BMS to be managed by external contractors. This means that knowledge of how the system works and the ability to make changes is hidden or intentionally restricted for the organisation that uses or even owns the building. The result is any significant changes often require the involvement of the management contractor which may, again, require site visits and additional cost to the existing service contract.
- Finally, complexity of the system. BMSs are complex systems with many components working in parallel. It is often difficult and requires expert (or system specific) knowledge to map a system's behaviour in relation to simple changes in setpoints. Prior MVS experience at Sackler Library (MVS A3.1.1) demonstrated that a seemingly straightforward action may lead to an unexpected counteraction that depends on the exact environmental conditions at the time.

The Oxford Behind the Meter (OBM) team within LEO have struggled with a number of these challenges over the project both within the University of Oxford and Oxfordshire County Council estates. This has been compounded by the Covid-19 pandemic which has meant many buildings have been closed or access heavily restricted, HVAC systems have been operated in different ways due to the need for increased airflow and building managers have been under pressure, rightfully prioritising the response to Covid-19.

To achieve step 10 of the MVS programme at Oxfordshire County Library, new functionality had to be programmed into the existing BMS software that would allow the scheduling of a load shedding event (demand turn-down). It was also the desire to have the ability to pre- and post-condition a building to ensure that the environment was in a state that it could stay within any set comfort limits throughout the service period. Over several months, the desired functionality was scoped in collaboration with the external BMS service contractor for Oxfordshire County Library, who sent an engineer to create the bespoke interface that can be seen in Figure 22. This process took more than 5 months at a contractor cost of £1,160 (not including Project LEO time equivalents). To put this into context, at a market rate of around £0.2/kWh and median capacity of 30 kW, hourly revenue is around £6 per hour of participation. This corresponds to over 190 hours of delivery to recoup just the cost of enabling scheduling, without accounting for other marginal costs of participation/utilisation such as shifted energy use or personnel time.

With such low revenues, similar if not lower than the personnel expense required to participate, the importance of minimising marginal costs through automation is clear. Two Market Stimuli

Packages (MSP)[3] have been proposed in Project LEO to support such costs. Using a maximum capacity of 60 kW, Oxfordshire County Council could receive between £85 - £177 in the first 6 months (depending on success of delivery) with the first MSP. For the second MSP, a £240 upfront payment would be available plus between £156-£312 in utilisation payments across 50-65 events, and finally a £120 bonus for completing the contract: in total up to £432 for the contract length. While these numbers fall short of the cost of enabling scheduling of the BMS it gives us a starting point to better understanding the barriers to market participation and how these might be overcome, particularly if factoring in additional benefits that come from more flexible building management systems.

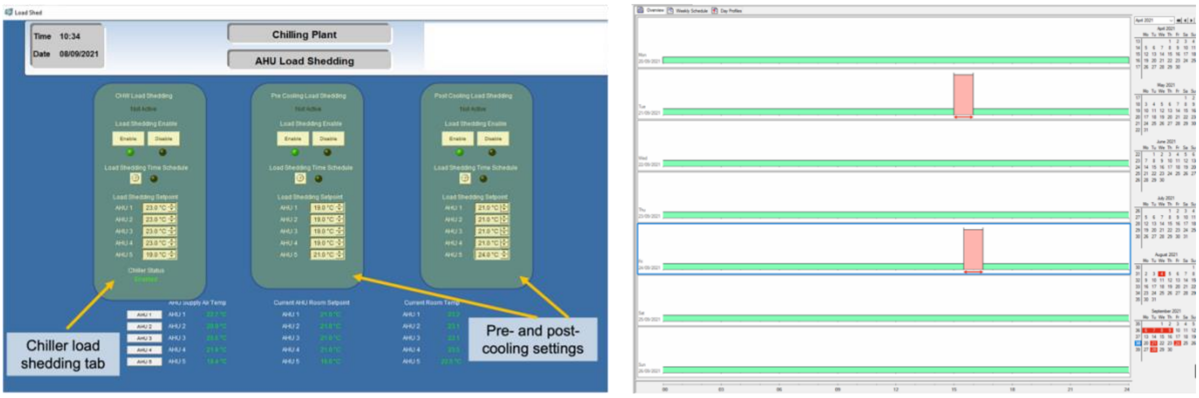


Figure 22: Newly procured scheduling interfaces on Oxfordshire County Library's building management system (BMS). Left: Air handling units (AHUs) temperature setpoints for pre-cooling, post-cooling, and load shedding. Right: Time scheduling calendar for load shedding.

Following completion of the software addition, it was possible for Oxfordshire County Library to participate in an MVS trial that demonstrated partial automation for dispatch with a scheduler. On the 24th of September 2021, the weather was warm enough to operate the chiller. Following a manual instruction from SSEN for a demand turn-down SPM flexibility request between 15:30 and 16:30, Oxfordshire County Library's BMS was scheduled to pre-cool the building between 14:30 and 15:30 by setting the setpoint temperature 1°C lower. This was then followed by the scheduled load shedding event between 15:30 and 16:30.

[3] Details of the TRANSITION Market Stimuli Packages are available on the TRANSITION website; accessed December 2021

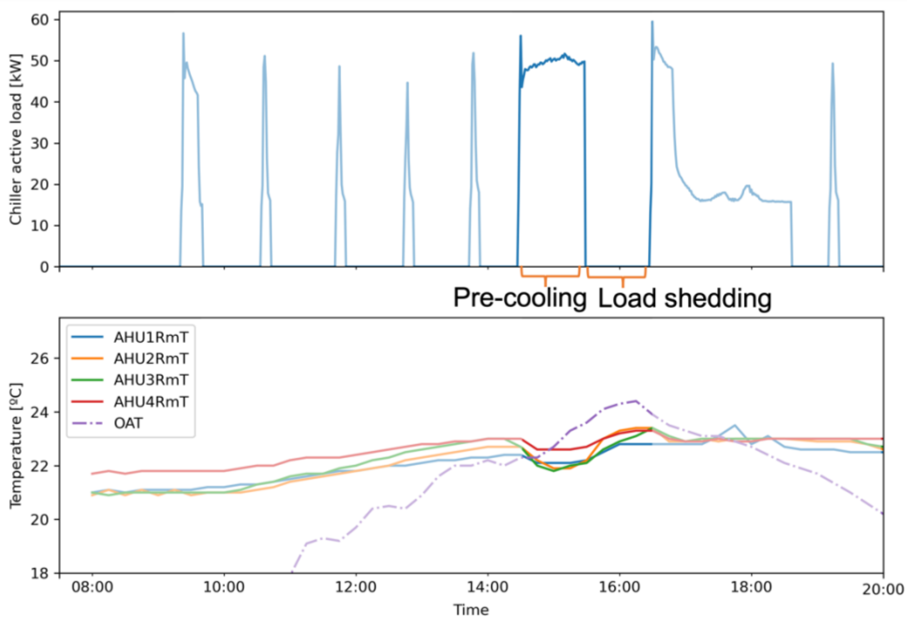


Figure 23: Oxfordshire County Library building response during MVSA3.5.1 which saw a pre-cooling period between 14:30-15:30, followed by a load shedding event between 15:30-16:30. Top: Chiller total active power. Bottom: room temperature measurements associated with each of the 4 AHUs (blue, orange, green and red) and the outside air temperature (purple).

The behaviour of the building during the trial is clear to see in Figure 23. The action of pre-cooling the building can be seen in the period 14:30 and 15:30 which led to an increase in chiller power, averaging around 50 kW, clearly resulting in a decrease in temperature during that time. At 15:30, the chiller power drops to 0 kW and is maintained at that level for the 1-hour service delivery period. The temperature inside the building can be seen to increase during this time, but due to a successful pre-cooling period, this does not rise above 24°C as it had done in previous trials.

It has taken considerable time, effort, and expense to implement the scheduling ability into Oxfordshire County Library's BMS to complete the MVS+ step 10. While this barrier is likely too high to currently encourage other buildings to enable this level of control for market participation, it is hoped that the learnings gained from this process will help inform ways in which this can be achieved more efficiently in future.

Step 13 – Automatic Instruction, Automatic Dispatch, Automatic Delivery

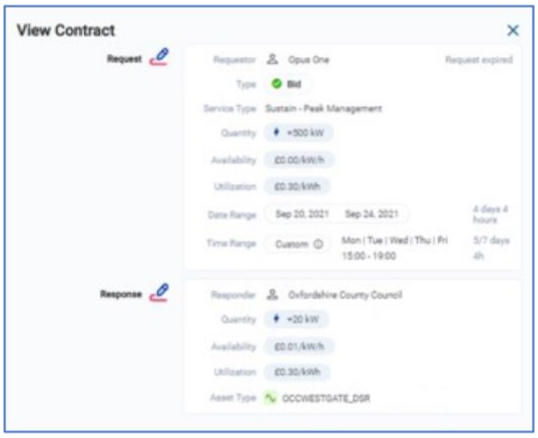
Step 13 of the MVS Programme is the second step labelled as an MVS+ and comes after the launch of the NMF and WSC platforms (step 12). The objective of trials associated with this step is to demonstrate an asset's response to a service delivery instruction that was automatically sent via the NMF. This represents a significant step towards full integration of assets with the operational market platforms.

The NMF was launched in September 2021 at the start of the Pre-Trial (Smoke Test) period. The intended operation for NMF-based instruction is as follows. If a service provider is selected to participate in an event as a result of the DNO's utilisation analysis, then the NMF will post the instruction to dispatch on the platform. The platform will send the service providers an email to inform that the intents to dispatch have been posted on the NMF.

Oxfordshire County Library – MVSA3.6.1 (21/09/2021)

As the NMF was launched at the end of the MVS period there was little opportunity for MVS+ trials to run and influence the design. This will instead happen as part of the Smoke Test period and will continue throughout Trial Period 1 (November 2021 – February 2022). For completeness of the MVS+ work, we included a Smoke Test trial that involved early testing for the intended automatic instruction functionality.

When launched, the NMF did not have the functionality of full automation to notify service providers. Instead, as a proxy, a scheduled instruction email was sent. A screenshot of the NMF interface where a service provider responds to a flexibility request by submitting a bid for availability price, utilisation price and quantity (of flexibility power) is shown in Figure 24 (left); the service offer was for 1 hour of 20 kW flexibility at a time between 15:00-19:00, 20th September – 24th September 2021, at a time notified by an instruction request. A screenshot of this instruction notification is shown in Figure 24 (right).



Utilisation Instruction	
Name of User	
Flexibility Service	Sustain - Peak Management
Unique identifier for Utilisation Instruction	Westgate-Library_Smoke-Test_SPM_21092021
Contracted Service Capacity to be delivered (in kW)	20 kW
Unique identifier for DERs involved	OCCWESTGATE_DSR_SP5114106119_F
Start date and time of delivery (DERs should be at full Contracted Service Capacity for this time)	21/09/2021, 15:00
End date and time of delivery (DERs should not reduce Contracted Service Capacity until after this time)	21/09/2021, 16:00
Date and Time issued	21/09/2021, 03:00

Figure 24: Example of interaction with the NMF at the end of the MVS+ period. Left: NMF interface where the service provider responds to a request for flexibility (in the pool auction). Right: NMF utilisation instruction email sent by SSEN to Oxfordshire County Council

Multiple LEO assets, including those of the Low Carbon Hub, have also completed this MVS+ step and other smoke tests, all contributing valuable learnings for desired NMF platform functionality that will be integrated in the rapid agile development during the Smoke Test period before the Full Trials.

Step 16 and 17 – Asset and Network Data Collection

Step 16 of the MVS Programme – Asset Data Collection and Validation – concerns the installation of monitoring at the asset or site to collect data during flexibility service delivery. This data will be required for validation of the service delivery by the DSO following an event. The monitoring may be new or additional to that already present, or this step might just demonstrate the collection of data from existing asset/site monitoring (such as MPAN metering).

Step 17 of the MVS Programme – Network Data Collection – is closely related to Step 16, but the difference here is the monitoring and data collection is focused on the network. This data is important in establishing the impact an asset or an asset's flexibility had on the node of the network where a potential constraint was identified as well as offering opportunity to cross-examine the asset's submitted data during validation and settlement procedure steps. As part of Project LEO, SSEN have installed 100 Eneida substation monitoring devices at secondary substation sites across Oxfordshire and made the data available for project partners through the Eneida data interface. As part of the NeRDA project,[4] SSEN are exploring ways to make data across their network at multiple voltage levels accessible and Project LEO is working closely with this project to establish use cases for such data.

Rose Hill Battery – MVS A2.15.1 (31/03/2021)

The trial and data collection presented in this section were conducted by Harry Orchard (LCH) and utilising the Eneida monitoring installed by SSEN.

Many of the trials presented above also satisfy Step 16 of the MVS Programme with local monitoring installed at the asset or site (via existing MPAN metering) providing the service. Half hourly site MPAN metering is the minimum required at present to take part in LEO trials, however, this will be assessed as part of future trials from both a DNO and service provider point of view. Depending on other activity at the site, the ability to accurately validate a service and therefore receive fair remuneration, might be more difficult from site monitoring. This can be seen when comparing the battery monitoring (blue) and site monitoring (orange) for Rose Hill Battery during MVSA2.15.1 in Figure 25 below.

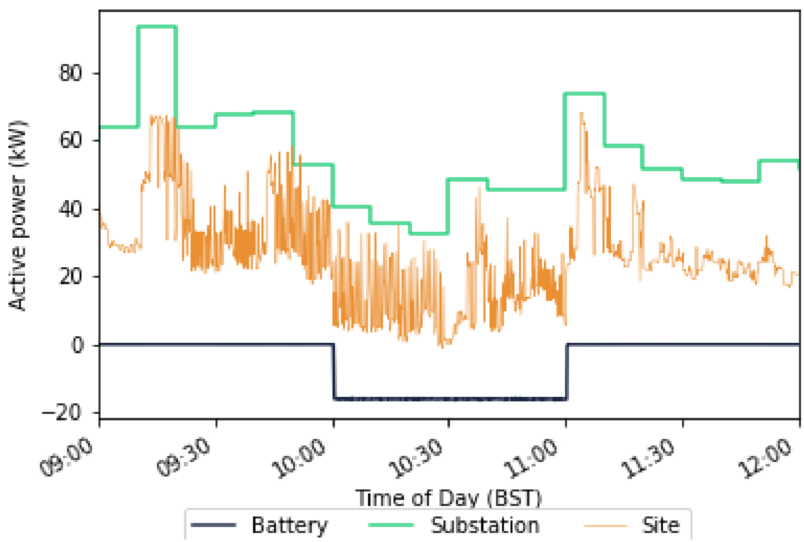


Figure 25: Power data acquired during Rose Hill trial MVS A2.15.1 at the battery asset (blue), the site (orange) and substation (green). Positive values indicate demand from the network (import).

Figure 25 also demonstrates how substation data from the installed Eneida monitoring (green) can be accessed and used to assess the impact of the flexibility service at the local substation. In the

[4] NeRDA (Near Real-time Data Access) project – Led by SSEN.

case of Rose Hill Primary School, the site dominates the demand on the LV feeder which connects to the local substation plotted above. It is clear there is a decrease in net demand on the feeder which is correlated with export from the battery behind the meter. The relative impact of a service on the network compared to that delivered by the asset will depend on the network topology and users connected in that locale with data like that presented above crucial for the DNO in making an assessment and modelling this as part of their Whole System Coordination (WSC) role.

Summary

This report provides a snapshot of the journey taken by some of the initial Project LEO assets through the Minimum Viable System (MVS) Programme – a programme of trials intended to support the development of asset capability required to deliver flexibility services within a local flexibility market. Each of the 10 MVS and MVS+ steps are discussed with an example trial presented from one of the assets that completed it, demonstrating how the step generated learnings which helped inform better asset operational behaviour or helped guide further development of the full end-to-end market process in preparation for the full trials.

With the project entering the Full Trials period, there has been a lot of learnings gained from the MVS Programme, both from gaining better understanding of asset operation within the context of flexibility service delivery, but also how to manage an iterative build-measure-learn approach within a complex multi-stakeholder system. The framework provided by the MVS Programme will continue for future assets if such support helps with asset enablement and market integration.

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