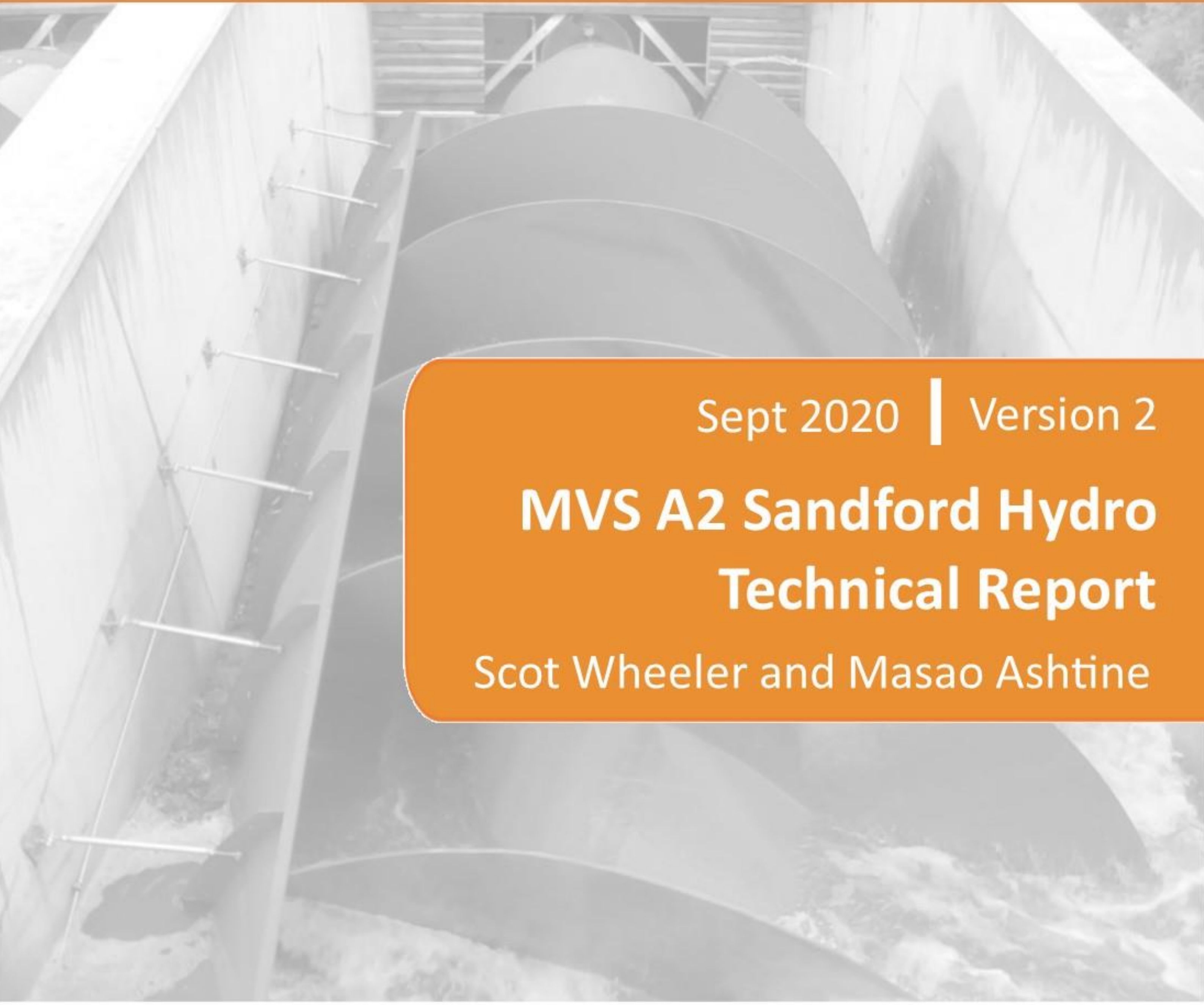
Local Energy Oxfordshire



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MVS A2 Sandford Hydro Technical Report

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Executive Summary

This report details the key learnings from the running of the first MVS (Minimum Viable System) trials at Sandford Hydro during Phase 1 of the LEO MVSs. MVSs are early stage feasibility trials which use the minimum set of requirements to test a new hypothesis or business model before sizeable investment of time or money are committed.

Sandford Hydro, located at Sandford-on-Thames just south of Oxford city centre, is a key asset for the Low Carbon Hub with an installed capacity of 440 kW. Sandford Hydro is a partially-dispatchable renewable generation source, some storage capability in the river may allow generation to be deferred (as opposed to curtailed) for short periods and fits within the 'Flexible Generation' MVS category of LEO. MVS trials run with Sandford Hydro provide a unique testing ground to investigate the provision of flexibility services to a DSO from a flexible generation asset of sizeable capacity.

This report focuses on the particular MVS A2.1 trial which involved two trial attempts (MVS A2.1.1 in November 2019, and MVS A2.1.2 in December 2019) for a demand turn-down (generation increase) service request. The primary purpose of the trials was to test the initial end-to-end procedure proposed by Project LEO, from identification of flexibility need by the DSO, to delivery of the service, within the context of a flexible generation asset.

Both trials resulted in a 'failure to deliver' as a result of higher than expected river levels due to heavy rain in the days preceding the trials. As a result, for the first attempt, a system issue meant that the screws couldn't be restarted because the head was too low, while for the second trial, the generating capability of the plant was significantly reduced, again due to low-head. Technical learnings from this MVS trial were thus limited in outcomes but key insights into the running of such flexibility services were gained, largely around the operational failure of turn-up/-down services.

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1 Introduction

Project LEO (Local Energy Oxfordshire) will demonstrate a Smart Local Energy System (SLES), at county scale, to maximise economic, environmental and social prosperity for the region. LEO is creating a local flexibility market to maximise utilisation of the electricity distribution network, at minimum cost, to provide best value for energy users, generators and Distributed Energy Resource (DER) owners alike.

Project LEO is taking an agile approach to developing and testing new flexibility services, business models and the multi-organisation procedure and communications required to operate a local flexibility market. Each minimum viable system (MVS) trial should represent the minimum stress set of participants and processes which are required to test a new process modification or asset use case. In doing so, new value can be identified and confirmed at a small, quick scale, before significant investment in time, money and user relations are committed; it is intended as a way to manage the risks associated with innovation in an uncertain, changing environment. All trials within Project LEO will be in response to artificial constraints.

The Low Carbon Hub (LCH), a social enterprise who develop community-owned renewable energy across Oxfordshire, have 47 renewable energy installations (or have aided in the development of said systems) with an annual generation potential of 4.5 GWh; 1 of these being a hydroelectric powerplant (Sandford Hydro). This report focuses on the Sandford Hydro asset site which is in Sandford-on-Thames with an installed capacity of 440 kW, producing roughly 1.6 GWh of energy annually to supply an equivalent of ~ 500 homes. The plant utilizes three Archimedes screws and more detail on its operations is given in later sections. This report specifically details the learnings captured from MVS A2.1 (two attempts: MVS A2.1.1 and MVS A2.1.2), the second MVS trial run as part of Project LEO. Sandford Hydro was used for this MVS trial which was coordinated between the Low Carbon Hub (LCH), Scottish and Southern Electricity Networks (SSEN), the University of Oxford (UoO), and Piclo.

The first trial attempt (MVS A2.1.1) ran on 28th November 2019 with the aim to demonstrate the dispatch of a LEO flexible generation asset in response to Distribution System Operator (DSO) advertised flexibility service request via the Piclo market platform and analyse the value of the service. However, due to heavy rain in the days leading up to the trial, the river levels up and down stream of the hydro were high, meaning there wasn't sufficient head to restart all screws for service delivery – a system issue, that Low Carbon Hub are in the process of addressing. Therefore, the first MVS trial attempt was classed as a 'failure to deliver'. The second trial (MVS A2.1.2) was scheduled in the window of 18th – 20th December 2019 with the aim of re-running the MVS trial to completion, however, this attempt too was rendered a 'failure to deliver' owing to reduced head conditions which reduced the amount of flexible capability at Sandford. The following sections will comb through the technical insights and learnings from these trial attempts to better understand the main successes and challenges faced in the use of prosumer assets for local flexibility services.

2 Sandford Hydro

Sandford Hydro is one of the LCH's main generation assets within its growing portfolio, at a nameplate capacity of 440 kWp. Commissioned in August 2017, Sandford Hydro is the largest community-owned hydro on the Thames. This achievement was largely gained through local community investment to create clean, green electricity at the site of the historic Lasher Weir. Local community members in Sandford and Kennington worked with the LCH to undertake the project management, raising £1.4 million in investment through a community share offer where £822,000 was raised in the first round of investment.

Figure 1: One of the Archimedes screws being transported to the Sandford Hydro site via barge along the Thames (left) and an aerial view of the site, including the weir (right) (Source: Low Carbon Hub)

Sandford Hydro is completely linked with the Environment Agency's remote monitoring system, allowing the latter to have active oversight of the river levels at the Hydro plant. The site is also equipped with a fish pass which, through an innovative design, includes naturalised and concrete sections that allow fish to migrate upstream beyond the hydro plant and move unperturbed by the site's operations. As previously mentioned, the plant has three Archimedes screws, each 14 m in length with a weight of 22 tons. The site has many monitoring conditions that control the operations of the screws with the following conditions affecting power output from the plant:

- Minor adjustments to the operation, including maintenance, can see a shutdown of the site for short periods of time.
- Extreme river conditions (excessively high upstream and downstream river levels etc) will force the plant to stop operations.

- Reductions in river flow (minimum flow rate of 2.5 m^3s^{-1}) will cause the screws to automatically slow down and the number of screws turning will gradually reduce until eventually they all stop. When the water flow increases, they will slowly begin to turn again. At the maximum flow rate of 24.9 m^3s^{-1} (total for all screws) the Environment Agency will begin allowing excess flow over the weir at the site.
- A power cut in the electricity grid will automatically stop the screws for safety reasons and will restart once power is restored to the grid.

Figure 2: Tailgate view of the Sandford Hydro Archimedes screw (left) and a close-up view of one screw at the site (right)

2.1 Trial Suitability

Sandford Hydro is a key asset of the LCH's portfolio. With an installed capacity of 440 kW, this site is one of LCH's larger generation projects and is expected to provide ~1.6 GWh of energy annually. Sandford Hydro has 3 Archimedes screws, with one screw having a variable drive and the other two operating on/off. Each screw has a flow capacity of 8.5 m^3s^{-1}. This allows access to the full range of 440 kW upward/downward flexibility should the river conditions allow. Due to the inherent nature of Sandford Hydro being intrinsically tied to environmental and river conditions, it provides a unique opportunity to explore a partially-dispatchable renewable generation asset, affording Project LEO the opportunity to fully trial the nuanced stages involved in these types of services. On the other hand, the environmental variability of Sandford Hydro may complement other resources such as solar generation in terms of seasonality, whereby winter months have higher river flow rates. This increases profile diversity and may increase the overall network capacity with both system types working in tandem to minimize renewable deficits in resource.

The site also has an export capacity of 400 kW (40 kW lower than peak capacity) which provides the opportunity for trials around flexibility services such as offsetting and capacity trading. At times of the year when the hydro can't run, it has 400 kW of spare capacity it could trade, while at times when the hydro can run at full capacity, it might look to procure an additional 40 kW of local capacity. Furthermore, the output of Sandford Hydro is close to the energy demand of the neighbouring village of Sandford and thus there also exists the opportunity for local energy trading to achieve net-zero community goals. Sandford Hydro facilitates LEO to learn how to operate flexible assets which have certain constraints in a flexibility market.

2.2 Project LEO Network Context

The LEO partnership has identified 12 primary focus areas for the LEO and TRANSITION trials (focus areas centred around Oxford are shown in Figure 3 below) which will see further monitoring installed. These areas are defined by the approximate area fed by SSEN's primary substations and selected based on the number of LEO's potential plug-in-projects which are within the areas. Sandford Hydro is located in Sandford-on-Thames, roughly 3.5 miles south of the Oxford city centre. Sandford Hydro generator is connected to a 11 kV/400 V, 800 kVA transformer on-site. This transformer is connected to the 33 kV/11 kV Kennington Primary Substation 800m away with a 6 MVA nameplate rating, operated by SSEN. Sandford Hydro is connected to the Kennington primary feeder E6L5. After Sandford Hydro, this connects to numerous secondary substations in the village of Kennington, up to Oxford Saïd Business School's Egrove Park. The village of Sandford on the east bank of the Thames sits the other side of an open point in the network, meaning it is fed from Rose Hill primary substation. This means, for the current network configuration, Sandford Hydro wouldn't be able to coordinate on network services below the same primary with Sandford (it could with Kennington), it may still be possible to look at local energy trading services between the two.

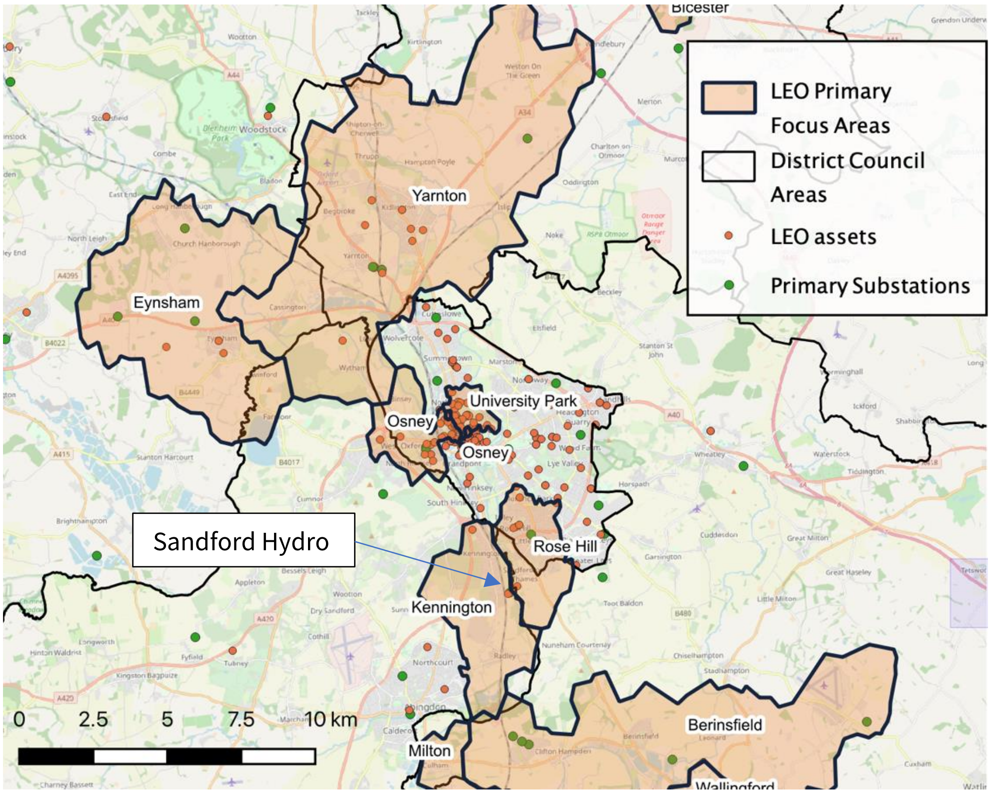


Figure 3: Map of LEO primary focus areas in Oxfordshire showing the location of the Sandford Hydro.

2.3 Site Specification

Table 1 below contains the LEO site specification data for Sandford Hydro. Certain fields may not be applicable to this site, while others are currently unknown or yet to be determined.

Table 1: Sandford Hydro Specification Data

Address	Sandford Hydro
Location (Lat, Long)	(51.711469, -1.236082)
Solar Generation Capacity (kW)	0
Other Generation Capacity (kVA)	440
Flexibility Type	Dispatchable power (hydro)
Flexibility Capacity (kVA)	400
Supply Connection Capacity (KVA)	10
Export Connection Capacity (kVA)	400
Voltage Connection (kV)	11
Connection Offer Reference (SSEN)	REDACTED
MPAN (Import)	REDACTED
MPAN (Export)	REDACTED
Secondary Substation Name	Generation
Secondary Substation Code	SHL11KVSS
Primary Substation Name	Kennington Primary
Primary Substation Code	4911
HV Feeder Name	E6L5 (POPLAR GROVE GARAGES)

2.4 Potential for Flexibility and Constraints

The Sandford Hydro flexibility can be tested through the control of the variable speed generator found at the site (one of three hydroelectric screws). A schematic of a typical Archimedes screw setup is shown in Figure 4 below. The LCH made the decision during the planning phase of the project to include this variable speed screw (140 kW) to allow for more efficient operations during times of lower river flow as the power output from the plant can be better maintained. The inclination of the three screws is fixed so cannot be adjusted as flow rate control. Sandford Hydro provides the opportunity for both turn-up/-down flexibility services, but these services must be in compliance with the environmental regulations along the river that control the river levels both up- and downstream.

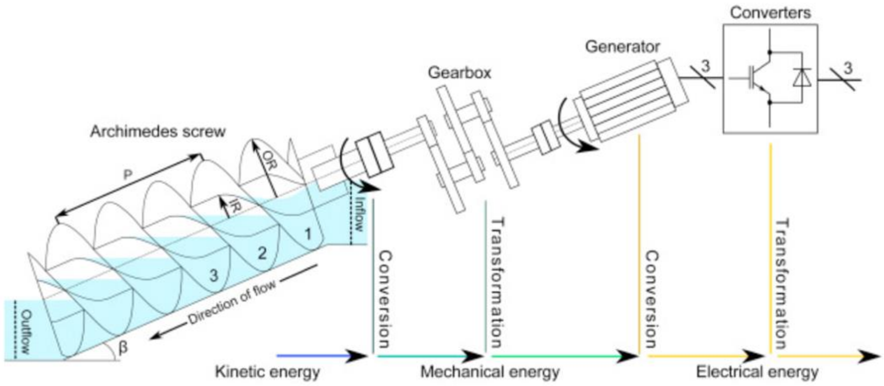


Figure 4: Schematic of an Archimedes screw used for hydroelectric generation (Source: Rohmer et al., 2016).

Under certain conditions, the river can be used as storage. By reducing the flow through the hydro, water can be backed-up on the stretch of river up-stream of the hydro. This can then be released later when the time suits, with the hydro running at an increased capacity due to the increased head resulting from the stored water. The hydro must abide by strict constraints when it comes to river levels. The technical internal report 'Sandford Hydroelectric System' details the technical operating parameters of the hydro and river system, and starts to develop the mathematical modelling to determine possible control strategies.

3 MVS A2.1 Trials at Sandford

Following up on the learnings from the first set of MVS trials at the Oxford Bus Company (MVS A1), the Sandford Hydro MVS trials were the first to test flexibility services from a generation asset type. The MVS notation at this stage of trials takes the form of 'MVS [MVS Group {A}][Generation Asset Type {2}][Trial Number {1}]' where the entries in the ' {} ' indicate the equivalent notation for the first trial of a generation service type as a reference. A later addition to the MVS notation following these trials includes an 'Attempt Number' after the trial number. Thus, the Sandford trials discussed herein are MVS A2.1.1 and MVS A2.1.2 but may appear as MVS A2.1 and MVS A2.2 in some internal documentation. Future trials will begin from MVS A2.3.1 to avoid any confusion. This section will discuss the main findings, both generic procedural and trial specific, from both of these trial attempts, presenting the key learnings and hurdles experienced in the execution of the Sandford trials.

3.1 Trial Details

The objective of the two MVS A2.1 trials was to demonstrate dispatch of a Project LEO flexible generation asset in response to an SSEN dispatch request through the Piclo platform and analyse the value of such a service. As previously mentioned, two trial attempts for MVS A2.1 were performed in the months of November and December 2019, both resulting in a failure to dispatch the flexibility service, each for different reasons. The Sandford A2.1 trial was also run to assess the impact of running this service on the river level upstream and downstream of the hydro asset.

3.1.1 Participants

Below is a list of the key trial participants with the form (**Role**: Company [*Persons responsible (Initials)*] for both trials):

MVS coordinator: Low Carbon Hub [Adriano Figueiredo (AF)]

Distribution System Operator (DSO): SSEN [Brian Wann (BW), Andrew Waterston (AW)]

Flexibility Market: Piclo [Kelsey Devine (KD)]

Service Provider: Low Carbon Hub [Adriano Figueiredo (AF)]

Data User: University of Oxford [Scot Wheeler (SW)]

3.1.2 Asset and Service Description

For both trial attempts, the flexibility service requested from the DSO (SSEN) was for a reduction in active power demand (equivalent to an increase in generation) for 1 hour with magnitudes of, -100 kW for MVS A2.1.1 and -50 kW for MVS A2.1.2. For both trial attempts, the active power response was set to be provided by the 140 kW turbine with a variable speed drive, controlled remotely through the hydro's main control system. Figures 5 and 6 below show how the services were setup for both trial attempts. It is important to note that the MVS A2.1.1/2 trial attempts are noted as

‘MVS A2.1’ and ‘MVS A2.2’ respectively as when the trial was run in 2019, the ‘attempt’ notation (described above) was not yet implemented.

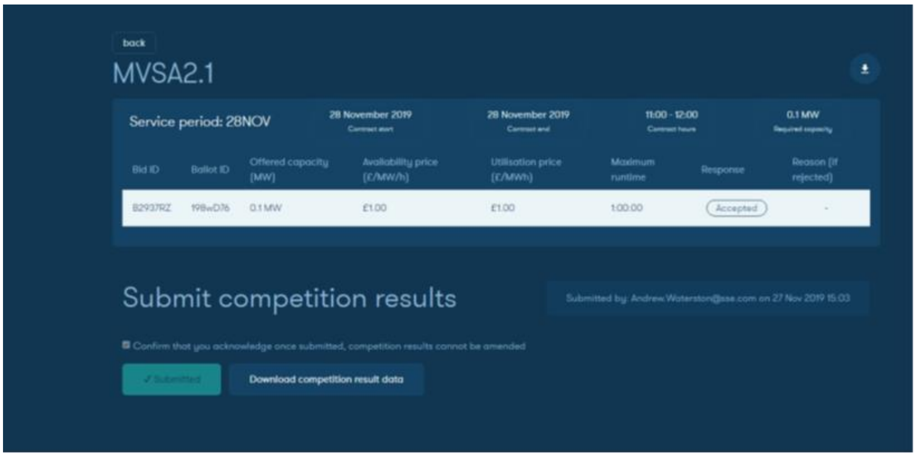


Figure 5: Piclo platform screenshot for MVS A2.1.1 on the 28th November 2019 which was requested to run between 11:00-12:00.

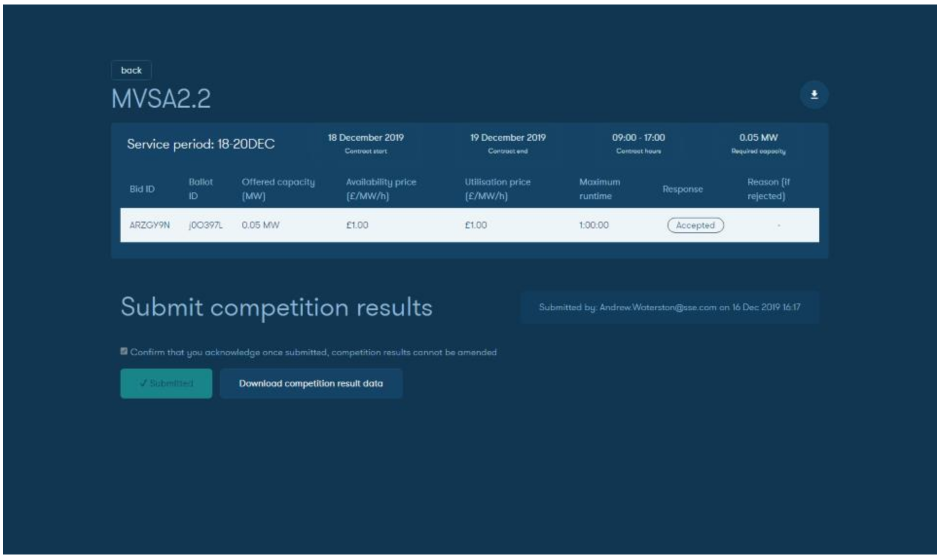


Figure 6: Piclo platform screenshot for MVS A2.1.2 on the 18th December 2019 which was requested to run within the time window of December 18-19, 2019, between the hours of 09:00-17:00.

3.1.3 Data

All data generated as part of these trials was shared through the Project LEO Data Log and can be accessed by project partners through the Project LEO Data Catalogue. Instructions for accessing this data for project partners can be found in the Project LEO Data Sharing Guide available on the Project LEO SharePoint. It is important to note however that as the Sandford MVS trials led to a failure to dispatch, power data coming out of the trials are limited in terms of investigating the flexibility service.

3.1.4 Risks

The following risks were identified and mitigated against as part of the trial.

Table 2: MVS A2.1 Risks

Risk	Associated step	Partner responsible	Impact	Likelihood	Total	Mitigation
Asset not available due to river conditions	9	Asset Owner (LCH)	Partial or failed dispatch	High	-	Inform SSEN with at least 1-hour notice of likely dispatch outcome

3.2 MVS A2.1 Trial Attempts

This section recaps the trial implementation based on the 14-step service delivery procedure (discussed further in the MVS A Procedural Learnings Phase 1 document). A summary of the main procedures undertaken for both trial attempts are listed through the tables below. Please note that as the trial attempts were not successfully completed, not all the 14 MVS procedure steps are listed below.

3.2.1 MVS A2.1.1

Table 3: MVS A2.1.1 Procedural Outcomes

Step	MVS Procedure	Actions taken	Supplementary Information
1	DSO identifies need for flexibility services	The artificial constraint was defined as requiring a -100 kW power shift, equivalent to reducing demand or increasing generation.	
2	DSO registers their constraint requirement	SSEN registered the constraint competition on the Piclo platform through upload of the relevant Excel spreadsheet.	

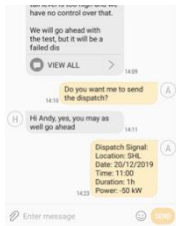
3	Service provider registers their flexible resource	The LCH registered Sandford Hydro as a flexibility resource on the Piclo platform via the Piclo asset spreadsheet.	
4	Service provider registers company with DSO	The LCH were assumed to be registered with SSEN as a flexibility service provider.	
5	Marketplace/DSO pre-qualifies the flexibility service	The LCH asset was assumed to be "Dispatch" ready	
6	Service provider to bid into auction	A proxy bid of £1 was submitted by the LCH through the Piclo platform. It was the only bid entered as part of the competition.	
7	DSO Selects winning bids	The bid was accepted by SSEN through the Piclo web interface.	
8	Flexibility Market platform facilitates communication dispatch service	SSEN sent the dispatch request at 15:49 on the 27th November 2019 requesting the service to be delivered at 11:00 (AM) for 1 hour on the following day. This was in the form of a text message sent from BW at SSEN to HO at LCH. Care was taken to ensure the asset didn't breach the contracted export capacity and power factor tolerances (0.95-1.05).	
9	Service provider dispatches services	Service not dispatched owing to a mechanical failure whereby one of the fixed speed screws could not restart after shutting down to raise river levels.	
10	Monitoring of the local substation		
11	Monitoring of the flexible resource		
12	Settlement	No settlement made.	
13	Research evaluation of specific MVS	The research evaluation is presented in the following sections.	
14	MVS procedure evaluation and feedback	The procedural learnings and feedback have been evaluated and are presented in the MVS Procedural Learnings Phase 1 (Jan 2020) LEO report.	

3.2.2 MVS A2.1.2

Procedure steps from Table 3 above were rerun for MVS A2.1.2, with steps 1-7 remaining the same except for step 1 were a power shift of -50 kW was requested from the DSO (SSEN) instead of -100 kW as seen in MVS A2.1.1.

Table 4: MVS A2.1.2 Procedural Outcomes (Steps 1 through 7 are not shown owing as they are identical to those of MVS A2.1.1 above).

Step	**MVS Procedure**	**Actions taken**	**Supplementary Information**

8	Flexibility Market platform facilitates communication dispatch service	SSEN sent the dispatch request at 14:23 on the 19th December 2019 requesting the service to be delivered at 11:00 (AM) for 1 hour on the following day. This was in the form of a text message sent from AW at SSEN to HO at LCH.	
9	Service provider dispatches services	Service not dispatched owing to the high river levels, resulting in low head.	
10	Monitoring of the local substation		
11	Monitoring of the flexible resource		
12	Settlement	No settlement made.	
13	Research evaluation of specific MVS	The research evaluation is presented in the following sections.	
14	MVS procedure evaluation and feedback	The procedural learnings and feedback have been evaluated and are presented in the MVS Procedural Learnings Phase 1 (Jan 2020) LEO report.	

3.3 Discussion of Results

As stated in the sections above, during preparations immediately prior to delivery, a fault was detected with one of the fixed-speed screws (not the generator itself) where the reduced head conditions prevented the screw getting up to the required speed, and therefore the screw could not be used for the trial. While delivery was attempted, there was only a partial delivery. This section outlines the main learnings from the MVS A2.1 trial attempts to better understand future steps in the execution of flexibility services of this type.

3.3.1 Procedural Learnings

More details on the procedural learnings from the Sandford Hydro MVS trial attempts can be found in the MVS A Procedural Learnings Phase 1 on the LEO SharePoint. This section will summarize these main findings, including the 'Process Maturity' of the MVS procedural steps to determine where further improvements can be built into the running of these flexibility services.

Although both trial attempts led to a 'failure to deliver', key learnings from these A2 MVS trials centred around the registration of the asset and service on the Piclo platform. An issue was raised with respect to terminology for the direction for power flex. Clarity on the registration of DSO constraints on the platform were improved, giving clear guidance on the use of 'deficit' / 'surplus' categories while a negative flex request was agreed to indicate a reduction in demand (or increase in generation). With respect to the bids themselves, troubleshooting was needed for viewing and selecting winning bids whereby some features in the platform are still under development and users needed to be guided through this process. Piclo also incorporated changes that allowed for more flexibility in the delivery of the service itself. The service period for an asset was changed such that it can be set for longer durations so that service delivery from the same MVS trial (future attempts) can be more streamlined.

Key learnings around the treatment of 'failures to deliver' were also gained from the MVS A2.1 trial attempts. Questions were raised around protocols that will guide parties around the penalties, notice periods, and the secondary bid process associated with assets and services that fail to deliver.

Within the LEO MVSs, 'Process Maturity' is used as a metric to quantify the evolution of an MVS; five categories of operation are identified: 'Unknown', 'Proxy', 'Manual', 'Partial Automation' and 'Full Automation'. Further details on the assignment of these categories can be found in the Procedural Learnings document. The table below gives the specific details of the process maturity of the MVS A2.1 trial (both trial attempts have been summarized for MVS A2.1).

Table 5: Process Maturity report for MVS A2.1. The colour code of the Process Maturity Stage (PMS) scores ranges from 1 (Red) to 5 (Green).

Procedure Step	PMS	PMS Score	Reason	To reach next stage
1	Unknown	1	No established methodology for identifying flexibility services as part of the MVS process.	DSO driven trial service criteria.
2	Manual	3	Spreadsheet is filled out manually and uploaded to the Piclo LEO platform.	Constraint registered through API interface.
3	Manual	3	Spreadsheet is completed manually for each asset and uploaded to the Piclo platform.	Asset managed through browser and API interface.
4	Unknown	1	No definition of DSO requirements or process for registering as a commercial supplier of flexibility	The requirements and process for registering as a commercial supplier of flexibility. A contract.
5	Manual	3	Asset status updated to 'Operation' by uploading new version of Piclo asset spreadsheet.	Asset managed through browser and API interface.
6	Manual	3	Manual determination of bid, input through Piclo platform.	Asset modelling informs bid price, input through API.
7	Manual	3	A manual selection of the winning bids by DSO personnel.	Aided decision making based on optimum financial option, delivery risk and system impact modelling.
8	Proxy	2	Dispatch signal is a text message between DSO and service provider via private phone.	Dispatch signal sent via the Piclo LEO platform, or official facilitator route.
9	Partial Automation	4	Remote operation of asset.	Automated response to a market signal or dispatch request

10	Partial Automation	4	There was no additional network monitoring by the DSO other than hourly current monitoring of the primary feeder. Manual retrieval needed.	Remotely accessible data with limited-to-no human intervention.
11	Partial Automation	4	Monitoring at 3-second resolution can be done remotely.	API/Remote access to data
12	Unknown	1	No settlement owing to failure to dispatch.	Successful delivery of service
13	Unknown	3	The research evaluation is the purpose of this report.	Automating this stage is not currently planned
14	Manual	3	MVS procedure feedback is provided through the live learnings document and digested in the generic MVS learnings report.	Automating this stage is not currently planned
Average		2.6		

The average process maturity for MVS A2.1 was rated at 2.6. Only two steps scored above 3 (steps 9 and 11) and thus there is scope to increase automation across all procedural steps. Particular focus should be made to the steps currently marked as 2, ‘proxy’, or below. Some steps remained ‘Unknown’ however owing to both trial attempts resulting in a ‘failure to deliver' with a lack of settlement.

3.3.2 Technical Learnings

1.1.1.1 MVS A2.1.1

The intention of this trial was to test the flexibility of the asset by responding to a -100 kW (demand turn down, generation increase) flexibility request. On the day of the trial the upstream and downstream river levels were very high due to heavy rain, reducing the potential to use the screws to back up the river. When preparing the hydro to activate for the trial, there was a fault detected in one of the screws at the sluice gate. There wasn’t enough head in the river to fully restart all the screws. Therefore, the flexibility service could not be provided. From Figure 7 below, it’s possible to see the attempt at service delivery, reducing the output of the hydro from 10:45 and switching back on around 11:00. Unfortunately, the issue meant an increased output by 100 kW could not be achieved; only a small transient with a maximum deflection of 13.1 kW above the 127.9 kW baseline is visible, contributing only 2.2 kWh of the expected 100 kWh over the 1-hour period.

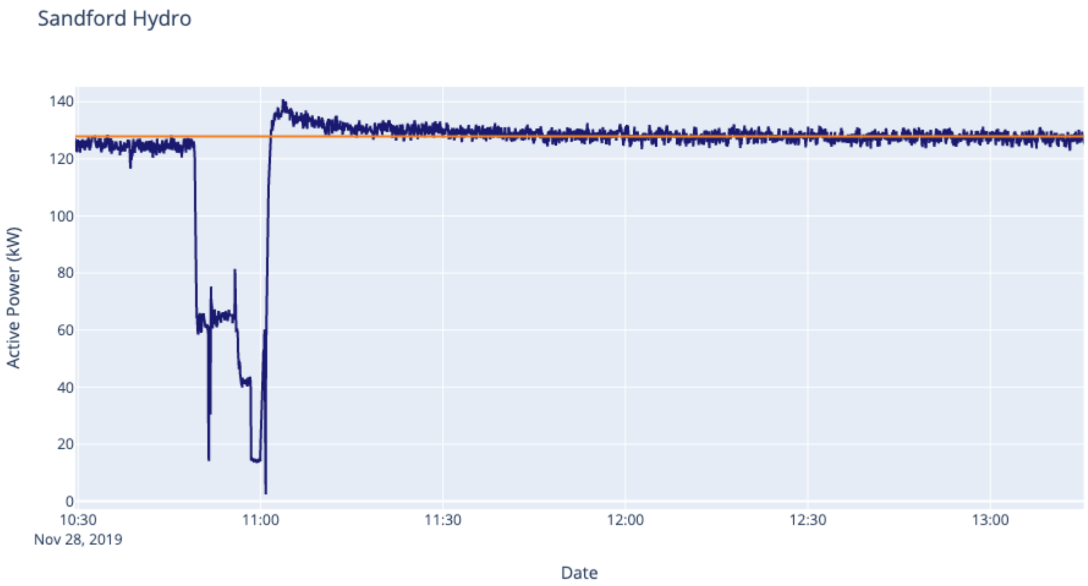


Figure 7: Active Power (blue) measured for MVS A2.1.1 at Sandford Hydro. The service was scheduled for 11:00-12:00. The orange baseline shows the average hydro output in the 30-minute period after the trial (12:00-12:30).

Despite not fully delivering the flexibility service, there was still value obtained from collecting power data for Sandford Hydro and uploaded to the Project LEO data log. The data fields available are 3 phase voltage and current; total active power, apparent power, reactive power, power factor and active energy exported. This data has been useful in providing further use cases data cleaning algorithm development. This processing will be important for later trials as baseline methodologies are explored. Figure 8 shows the system voltage raw data and post cleaning. Spikes between 12:00 and 15:00 were identified as outliers using a z-score method and filled using linear interpolation. Code and documentation for the cleaning methods developed are available on the Project LEO bitbucket repository.[1]

[1] Project LEO code repository: https://bitbucket.org/projectleodata/project-leo-database/src/master/

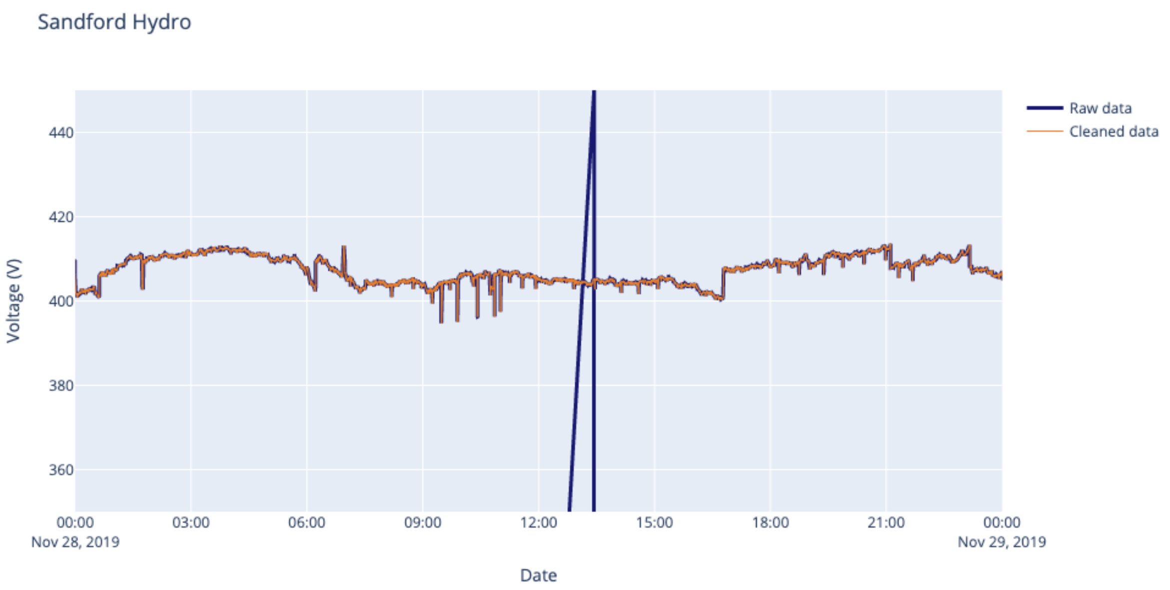


Figure 8: Raw and cleaned voltage data recorded for MVS A2.1.1. The spikes observed between 12:00 and 15:00 have been removed as outliers using a z-score method and filled using linear interpolation.

Due to the failure to deliver, no further technical analysis is presented at this stage.

1.1.1.2 MVS A2.1.2

This trial was intended as a second attempt at MVS A2.1.1, continuing from where the previous trial has failed. The flexibility service was reduced to -50 kW in the hope this would more achievable for the asset considering the conditions. However, due to heavy rain between identifying the trial date and the day of the trial, the capacity of the plant had decreased to just 30 kW due to reduced head. The trial was delayed by a couple of days to see if the river conditions would improve but they did not. This, alongside MVSA2.1.1, demonstrates that the capability of the asset to meet a demand response is heavily dependent on river condition stability, and it is hard to predict the ability to match the requested demand more than a few days in advance. This may have implications on the type of service which the hydro can participate in.

In addition, power to the Frerlogger data recorder was cut while doing some maintenance shortly before the start of the trial. Once power was restored, the recording software did not reconnect to the meter automatically as expected. Following the trial, it’s now known that the recording software must be restarted, and processes are now in place to ensure this is done after power outages.

As the trial didn’t proceed, not further technical analysis was completed as part of this trial.

3.3.3 Commercial Learnings

Local flexibility services involving generation assets potentially offer asset owners increased revenue streams through additional value stacking opportunities. These could include DSO procured services such as Constraint Management or Peak Management, DSO enabled services between other local actors such as Offsetting or Capacity trading, and market services such as energy trading or risk management. MVS trials at Sandford Hydro should be capable of providing insight into all of the services. Peak management is particularly interesting for Sandford Hydro due to the relatively short timeframe available in river storage, while the ability to control power factor might offer new value through reactive power constraint management services. Through Project LEO's Smart and Fair Neighbourhood projects, the potential opportunities which come from coordinating the operation of Sandford Hydro with the local energy context will be explored. There is potential within the Offsetting and Capacity Trading services to take make the most of complementary energy assets (e.g. solar PV).

As both trial attempts led to a failure to deliver owing to mechanical issues and high river levels, commercial learnings and value that were extracted from these particular trials were limited. Generation assets, particularly those influenced by weather events such as rising river levels, can face difficulty in scheduling DSO service requests. In order for commercial value to be maximised from these services, both the DSO and service provider may require accurate forecasting services integrated with market dynamics which protect both parties from failures to deliver. This is likely to have an impact on the levelised cost of service delivery. Despite the failure to deliver services in the trials reported, the trials have successfully motivated further thinking around contracts and procedures for handling disrupted services at multiple timescales which can be tested in future trials.

3.3.4 Social Learnings

Following the running of this first phase of MVS trials, a stakeholder mapping exercise was carried out to identify important stakeholders and their roles within the service delivery. The intention is to use this during the initiation phase of future MVS trials, and to inform ongoing engagement with stakeholders. The first stage is to categorise the stakeholders into three core themes: 'Critical to Success', Adds Value' and 'Keep Informed'. The results are summarised in Table 6 below. The second stage is to identify a level of engagement during the different stages of trial development. Table 7 shows a heat map of how the engagement process could have worked for the Sandford Hydro MVSs.

Table 6: Stakeholder categorisation for Sandford Hydro

Stakeholder categorisation sheet **What is the objective/activity**: Development and testing of MVSA2 – Sandford Hydro generation turn up/turn down flexibility services and assessment of the impact on river level upstream and downstream of the hydro asset.		
Critical to success - i.e. who has authority and has to say "yes" for things to proceed, and/or is responsible for "doing".	**Adds value** - i.e. who is responsible for "doing" added value tasks and/or needs to be consulted to develop a better outcome.	**Keep informed** - i.e. wouldn't materially alter or impede the achieving the objective, but are necessary to keep informed.
Who has authority? Environment Agency – as regulator for watercourse Sandford Hydro Community Interest Company Low Carbon Hub – as developer and operator/owner of asset meter data SSEN – simulating grid constraints for testing, installation of monitoring equipment at substation, undertaking monitoring. LCH investment committee PiP board – approval of progress Piclo – communication with Piclo LEO platform for testing. **Who is responsible for implementing?** Low Carbon Hub – hydropower plant management, calculating loads/assessing feasibility, remote automation and control University of Oxford – Data validation where required SSEN – providing simulated grid constraint, verifying flex event as	**Who needs to be consulted?** University of Oxford – as data users Community investors – to understand how flexible generation will/will not impact their investment. Environment Agency – for allowing services to run. Relationship with lockkeeper also important.	**Who is interested?** All groups who are either "critical to success" or "adds value". LEO Partners otherwise uninvolved in the MVS. Local community – awareness to avoid undue concern when river levels vary/hydro operating at unexpected times Local environmental interest groups/local communities (passive interest). Project Monitoring Officers and PFER. Press.

happened?, installing monitoring equipment. Piclo – facilitating the relevant information being registered on the Piclo LEO platform.		

Table 7: Ongoing stakeholder engagement strategy heat map

Stakeholder	**Inception**	**Feasibility**	**Funding**	**Developing the system**	**Operation / testing**	**Dissemination**
Environment Agency	None	Fully	None	Fully	Fully	Some
Sandford Hydro Community Interest Company	Some	Some	Some	Some	Some	Some
Low Carbon Hub	Fully	Fully	Fully	Fully	Fully	Fully
SSEN	Some	Fully	None	Fully	Fully	Fully
Low Carbon Hub investment committee	Low	Low	Fully	Low	Low	High
PiP Board	Fully	Fully	Fully	Fully	Fully	Fully
Piclo	Some	Fully	Low	Some	Fully	Fully
University of Oxford	Some	Fully	Low	Fully	Fully	Fully
Community investors	None	None	Fully	Low	Low	Some

The number of critical stakeholders at this early stage of trials is quite small for Sandford Hydro due to it being owned and operated by the Low Carbon Hub, one of the LEO partners; this is one reason it's so useful for early stage MVS trials. The Environment Agency is a critical stakeholder, particularly when it comes to variable operation of the hydro, both the capacity and temporal availability. It is important that LEO trials stay well within the constraints imposed by the EA, for river operation (nearby lock movement) and flood risk mitigation reasons.

3.3.5 Regulation and Policy Learnings

At present, the key regulations which could restrict operation of the hydro are those required by the Environment Agency in order for them to manage river safety and operation, for instance, the minimum flow rate at the hydro is 2.5 m^3s^{-1} to allow sufficient flow through the fish pass. Further details of technical regulations can be found in the internal 'Sandford Hydroelectric System' modelling report available on the Project LEO sharepoint.

3.3.6 KPIs

As the Sandford MVS trials were a 'Failure to Deliver', the following table of KPIs is largely listed as 'not-applicable' (N/A), but the KPIs themselves have been recorded in this report for reference to those being used to monitor MVS trials learnings and outcomes.

Table 8: Specific MVS Key Performance Indicators (KPIs) with values where applicable for MVS A2.1.1 Sandford Hydro

KPI	Value
Capacity under flexible control	100 kW
Impact on network utilisation (constraints)	N/A
Service response time	N/A
Levelized cost of flex event (full flex process, cost per kW and cost per kWh)	N/A
Additional generation capacity unlocked	N/A
Number of customers participating in the Project LEO service	1
Number of vulnerable customers / 'energy poor' customers participating in the Project LEO service	0
Net benefit to participants	N/A
Estimation/measurement of CO2 impact of the Project LEO service	N/A
Impact on non-participants	None

4 Summary and Future Work

MVS A2.1.1 and MVS A2.1.2 were the first Project LEO trials attempted on a flexible generation asset, that being Sandford Hydro. The micro-hydro on the River Thames just, south of Oxford city, is capable of providing a maximum flexibility capacity of 440 kW but the availability is highly dependent on river conditions. Sandford Hydro is an interesting asset for Project LEO to study as it could benefit from all service types being tested within Project LEO, including the capacity trading and offsetting services. However, utilising its full potential will require a thorough understanding of the flexibility market mechanisms, ability to forecast availability and integrate it into an optimised control strategy.

The first trial, MVS A2.1.1, was attempted on 28th November 2019, and was scheduled for a -100 kW flexibility service. However, river conditions on the day meant there wasn't enough head at the hydro to fully restart the screws. This led to a 'failure to deliver' with only about 5% of the expected energy being delivered. A second attempt at delivering the service was scheduled for a window between 18th and 20th December 2019, with a reduced service of -50 kW. However, heavy rain in the days leading up to the service delivery window meant that again, it was not possible to dispatch the hydro, again leading to a 'failure to deliver'.

Despite not being able to deliver the flexibility service, the trials were still valuable to test the broader processes of flexibility procurement and delivery which Project LEO is developing. Communications between actors and the integration of flexibility competitions and procurement through digital platforms were tested. In particular, questions raised regarding how each actor should respond to a failure to deliver will be important in informing the development of contracts and market dynamics including penalty regimes and reliability metrics.

Owing to the challenges faced with a variable generation asset which is so highly dependent on environmental conditions such as the hydro, recognition was given to the need of better understanding generation assets that can benefit from a degree of forecasting. Preliminary research has been started on hydroelectric forecasting to improve the scheduling of flex events; Figure 9 shows the modelling scheme for 4 different operating modes for the hydro. Owing to the vulnerability of these events to the rise and fall of river levels, the improved modelling of the river and hydroelectric system will allow the LCH to act as a more informed service provider, enabling a greater degree of flexibility with reduced uncertainty.

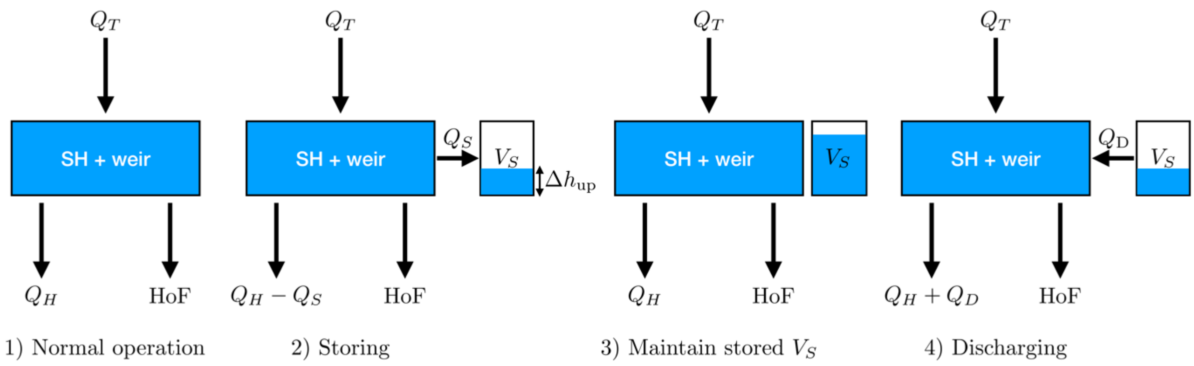


Figure 9: Hydro river system storage modelling scheme depicting 4 different operating modes

Project LEO sees this as not only an added benefit within the MVS trials but a tool from which future local energy system trials can benefit. It is intended that future MVS trials involving Sandford Hydro (and subsequently other relevant generation assets) will incorporate a degree of forecasting to reduce chances of dispatch failures.

Future MVS trials with Sandford Hydro will continue to advance the use of this generation asset for the provision of DSO procured and enabled flexibility services. Sandford Hydro has also been identified as one of the Project LEO Smart and Fair Neighbourhood locations. Here the focus will be on how a local asset capable of providing flexibility can catalyse further value for the local neighbourhood around it. Initial progress, however, will need to revolve around issues flagged in the previous A2 trials. As seen with the 'Process Maturity' of the trials presented, more automation of procedure steps, particularly around the delivery of the flex service and the retrieval of data post-event, are needed. Weir automations and more streamlined communications around the dispatch and delivery of services from Sandford Hydro will allow LEO to increase learnings coming from generation assets and their scheduling. This level of automation will also prove particularly useful within more advanced MVS trials that test the provision of flexibility services such as offsetting, where a well-coordinated delivery of service is crucial to the DSO and asset owners.

5 Glossary

Best efforts have been made throughout the document to use accepted terminology common to the UK electricity industry and DSO industry. For clarity, some key terms used in this document are defined below.

Term	Definition
Aggregator	An aggregator is a company who acts as an intermediary between electricity end-users, DER owners and the power system participants who wish to serve these end-users or exploit the services provided by these DER. The aggregator groups distinct agents in the electric power system (i.e. consumers, producers, prosumers, or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to system operators.
BMS	Building Management System
BSP	Bulk Supply Point: A node on the distribution network between extra high voltage and high voltage. Typical voltage level (kV): 132/33.
Data User	A party or individual who requires access to some or all of the data generated as part of the MVS trial for analysis, evaluation and/or learning generation.
Delivery	The fulfilment of the flexibility service as per the dispatch instruction.
DER (Asset)	Distributed Energy Resource connected at distribution level.
DER (asset) Owner	The legal owner of a DER (asset).
Dispatch	Instruction sent by the DSO to the Service Provider to initiate the flexibility service.
DNO	Distribution Network Operator.
DSO	Distibution System Operator. A party that takes on the role of system operation. A DSO securely operates and develops an active distribution system comprising networks, demand, generation and other flexible DERs.
DSR	Demand Side Response. Varying the demand of a DER, such as a building, to offer flexibility.
EA	Environment Agency
Flexibility Market	The arena of commercial dealings between buyers and sellers of Flexibility Services.
Flexibility Service	The offer of modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a Service within the energy system.
Grid	The electricity distribution network.
GSP	Grid Supply Point: The point where the distribution network connects to the transmission network. Typical voltage level (kV): 400/132.
HVAC	Heating, Ventilation and Air Conditioning
KPI	Key Performance Indicator
LCH	Low Carbon Hub
LEO	Local Energy Oxfordshire
MIC/MEC	Maximum Import Capacity/Maximum Export Capacity

MPAN	Meter Point Administration Number
MVS	Minimum Viable System. A minimum stress set of participants, technology and processes required to trial new system innovation.
MVS Coordinator	A single person taking on the responsibility of 'Project Manager' for the specific MVS trial, they are responsible for coordinating other partner coordinators to ensure the MVS documentation gets completed.
OBC	Oxford Bus Company
OBM	Oxford Behind the Meter: A plug-in project within Project LEO.
OBU	Oxford Brookes University
OCC	Oxfordshire County Council
OCityC	Oxford City Council
Partner Coordinator	The lead person from each organisation involved in the MVS trial that coordinates the activity of that organisation in the trial, and has responsibility for completing the MVS documentation relevant to their organisations role.
Plug-in Project	A flexibility asset or system being developed as part of LEO which is capable of 'plugging-in' to the flexibility market.
PMS	Process Maturity Stages. A metric measuring automation of a process.
PSS	Primary Substation: A node on the distribution network between high voltage and medium voltage. Typical voltage level (kV): 33/11.
Service Provider	Those parties able to offer Flexibility Services. Not necessarily the Asset Owner.
Settlement	A financial transfer to the Service Provider following the successful delivery of the instructed Flexibility Service.
SFN	Smart and Fair Neighbourhood
SSEN	Scottish and Southern Electricity Networks
Technology Platform	A market where user interactions are mediated by an intermediary, the platform provider, and are subject to network effects. As opposed to a marketplace or trading exchange, a platform intermediary must offer inherent value beyond the simple mediation process for the two sides of the market.
UoO	University of Oxford