WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

Solar Storage

WPD_NIA_004

NIA MAJOR PROJECT PROGRESS REPORT

REPORTING PERIOD: APR 2015 – MAR 2017

Low Carbon Networks

Report Title	:	Solar Storage
Report Status	:	Final
Project Ref	:	NIA_WPD_004
Date	:	28/04/2017

Document Control

	Name	Date
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Approved (WPD):	Roger Hey	02/05/2017

Revision History

Date	Issue	Status
10/04/2017	0.1	Draft
28/04/2017	0.2	Final Draft
28/04/2017	1.0	Final

Contents

Glossary

Term	Definition
BAU	Business as usual
BMS	Battery Management System
BRE / NSC	Building Research Establishment / National Solar Centre
BSRL	British Solar Renewables Limited
DG	Distributed Generation
DNO	Distribution Network Operator
EFR	Enhanced Frequency Response
GB	Great Britain
HV	High Voltage
IPR	Intellectual Property Register
LCT	Low Carbon Technologies
LV	Low Voltage
NIA	Network Innovation Allowance
PEA	Project Eligibility Assessment
PV	PhotoVoltaic
SOC	State of Charge
WPD	Western Power Distribution

1 Executive Summary

Solar Storage is funded through Ofgem's Network Innovation Allowance (NIA). Solar Storage was registered in April 2015 and will be complete by April 2018.

Solar Storage aims to install and operate a battery at Higher Hill farm to;

1) Quantify the potential value to network operators and others of integrating storage with solar generation by demonstrating a set of use cases.
2) Use real-world operation of an integrated utility scale storage / generation system to provide data to regulators and potential investors.
3) Demonstrate safe, reliable operation of the system under operational conditions.

The battery chemistry is Lithium Iron Phosphate, which is less energy dense than Lithium Ion batteries but has the advantage of having greater thermal stability and is at lower risk of overheating.

This report details progress of the project, focusing on the period to April 2017.

1.1 Business Case

The reduction in the cost of battery storage, along with increased demand for fast response flexibility services such as Enhanced Frequency Response (EFR), has generated a huge amount of interest in battery storage technology. Battery installations can vary in size from domestic to large grid connected installations. This project considers the use cases for a moderately sized battery (300kVA, 640kVAh) co-located with a solar farm.

Integrating storage with renewable generation offers a route to addressing some or all of the following issues:

(i) Renewable generation does not predictably match peak local demand.
(ii) Renewable generation is often 'spikey', which can introduce short-term impacts on grid voltage or other quality of supply factors.
(iii) Unpredictability, lack of control mechanisms and power quality mean grid operators use very conservative rules to allocate grid connections.
(iv) Grid operators have to introduce new equipment to manage power quality, a service which could be provided by operators of utility scale renewable installations.
(v) Without the ability to respond quickly to local surges in load, grid operators manage network capacity within tighter limits than might otherwise be possible.
(vi) Introducing two or more active storage or quality management devices onto the same HV circuit may cause them to interact with each other and have a negative impact on power quality.

Using flexibility services provided by a battery is expected to be cheaper than conventional reinforcement. The figures below are taken from the Project Eligibility Assessment (PEA):

- DNO annualised cost for current conventional method is £570k/MVA.
- DNO potential annualised cost of the Method being trialled is (£13K/MVA+£5k)/year.
- DNO expected financial benefit is £570k/MVA-(£13k/MVA+5k)/year.

The battery used in Solar Storage has an additional benefit, in that it is containerised which should make not only installation, but any subsequent relocation simpler. If a battery can be relocated cost effectively then this suggests that battery storage can provide a DNO with a temporary solution where future load/generation profiles are hard to predict. It is expected that after a term of deferral there will be more certainty over the case for traditional reinforcement, applying a smart technique or the commercial purchase of flexibility services, and that the temporary use of a battery will therefore reduce the risk of stranded assets.

1.2 Project Progress

This is the first progress report. It covers progress from initial registration in April 2015 to the end of March 2017.

Much of the work in the early part of the project related to specifying and sourcing the battery. As this type of battery is not yet an "off the shelf" commodity item, this process was quite involved and required drawing up a lengthy complex contract to cover supply, installation and support.

To enable the battery installation, work also took place to;

- Agree the site layout,
- Gain planning permission,
- Install cables prior to the battery installation,
- Carry out civil works,
- Install the battery,
- Complete site works, and
- Test the battery.

Additionally work was required to establish communications to the battery and some revisions to the battery control software, Resolve, were made to better support the use cases.

The process to obtain a lease for the battery site met with a number of challenges and, together with some on-site construction issues, this lead to a delay in the construction schedule.

The battery was commissioned in October 2016 and since then the battery has been operated against a pre-agreed test schedule; however there have been a number of operational issues that have interrupted the testing process. While the availability of the battery, as calculated by the term included in the contract has been over 95%, this does not reflect the degree to which the testing has been interrupted by unexpected battery behaviour and uncertainty over whether the battery can be safely operated.

Recently there have been changes in key personnel at both BSRL and BRE, in addition to a change in the WPD project manager in December 2015 and a change of ownership structure at BSRL.

Some analytical work that was not dependent on operational battery data has already been carried out. The first piece of analysis was carried out by Geoff Foote of SRI and considered the potential for revenue improvement using a battery. This showed that revenue improvement was possible but relatively low for a battery of the scale of our installation. This confirms the view that the business case for a battery is likely to require multiple income streams.

Subsequently an analysis of the existing regulatory structure and the impact of Balancing Mechanism costs on the business case for larger batteries was carried out by John Lindup of Utilities Insight with the final report being published on the WPD website. This work was originally intended to be completed by Elexon. Some of the issues raised in this report were included in the response to the joint call for evidence by Ofgem and BEIS in December 2016.

A power quality monitor has been installed adjacent to the battery but the installation of a further power quality monitor, at the primary substation feeding the battery, has yet to take place. The plan is to obtain a better baseline assessment of power quality at the primary before assessing the impact of the battery.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The Solar Storage Project Review Group meets on a bi-annual basis. The role of the Project Review Group is to:

- Ensure the project is aligned with organisational strategy;
- Ensure the project makes good use of assets;
- Assist with resolving strategic level issues and risks;
- Approve or reject changes to the project with a high impact on timelines and budget;
- Assess project progress and report on project to senior management and higher authorities;
- Provide advice and guidance on business issues facing the project;
- Use influence and authority to assist the project in achieving its outcomes;
- Review and approve final project deliverables; and
- Perform reviews at agreed stage boundaries.

1.3.2 Project Resource

Organisation	Staff
BSRL	Luke Hosking - Overall project manager for BSRL Christie Sims – Battery operation and analytics
RES	Tracy Scot – Project manager for RES Simon Johnson - Resolve manager BYD support accessed via RES.
BRE/NSC	Christine Coonick
Argand	Fraser Durham Ben Markille
Utilities Insight	John Lindup
SRI	Geoff Foote
WPD	Jenny Woodruff – project manager Christian Hjelm (or nominated Team Manager) – Project Sponsor

1.4 Procurement

The following table details the current status of procurement for this project.

Provider	Services/goods	Area of project applicable to	Anticipated Delivery Dates
RES	Battery, installation and support	As per services/goods description	Construction complete – support ongoing
BSRL	Battery operation and analytics		Ongoing till end of project
SRI	Techno-economic modelling		Complete
Utilities Insight	Regulatory analysis		Complete
Argand	Power Quality Monitoring		Installation expected in April 2017 with support to end of project
BRE/NSC	Process validation and oversight		Test schedule review completed.

			Operational review expected May 2017

Table 1-1: Procurement Details

1.5 Project Risks

A proactive role in ensuring effective risk management for Solar Storage is taken. This ensures that processes have been put in place to review whether risks still exist, whether new risks have arisen, whether the likelihood and impact of risks have changed, reporting of significant changes that will affect risk priorities and deliver assurance of the effectiveness of control.

Contained within Section 7.1 of this report are the current top risks associated with successfully delivering Solar Storage as captured in our Risk Register. Section 7.2 provides an update on the most prominent risks identified at the project bid phase.

1.6 Project Learning and Dissemination

Project lessons learned and what worked well are captured throughout the project lifecycle. These are captured through a series of on-going reviews with stakeholders and project team members, and will be shared in lessons learned workshops at the end of the project. These are described further in Section 5 of this report.

Publications

The project has been featured in press releases by RES and BSRL, but has also been referenced by Utility Week. The project has been included in Power Lines and in the WPD parent company magazine. Supporting information has been given to Cardiff University for their work on the public perception of energy storage technologies.

Site Visits.

In addition to site visits organised by BSRL and RES, there has been a demonstration of the battery to Innogy which was well received. Plans for a visit by the local MP are at an early stage.

Presentations.

An overview of the project was presented at the 2015 LCNI. The project will feature in upcoming presentations at EDIE live and at the Balancing Act event.

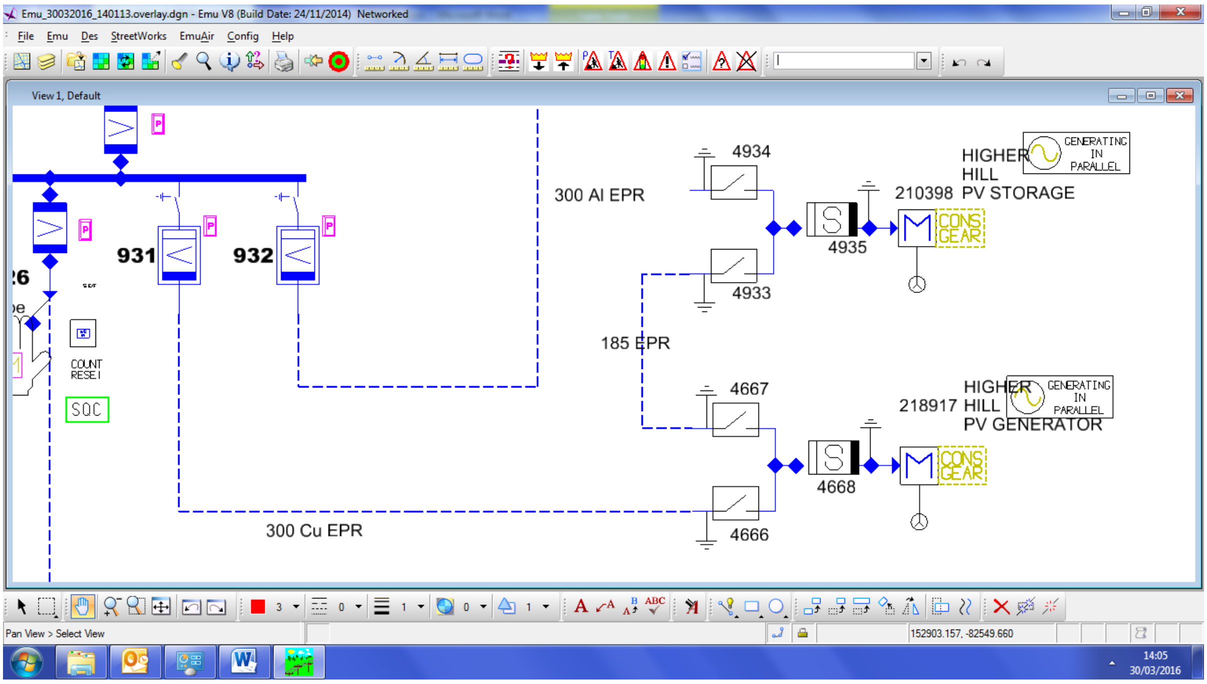
2 Project Manager's Report

2.1 Project Background

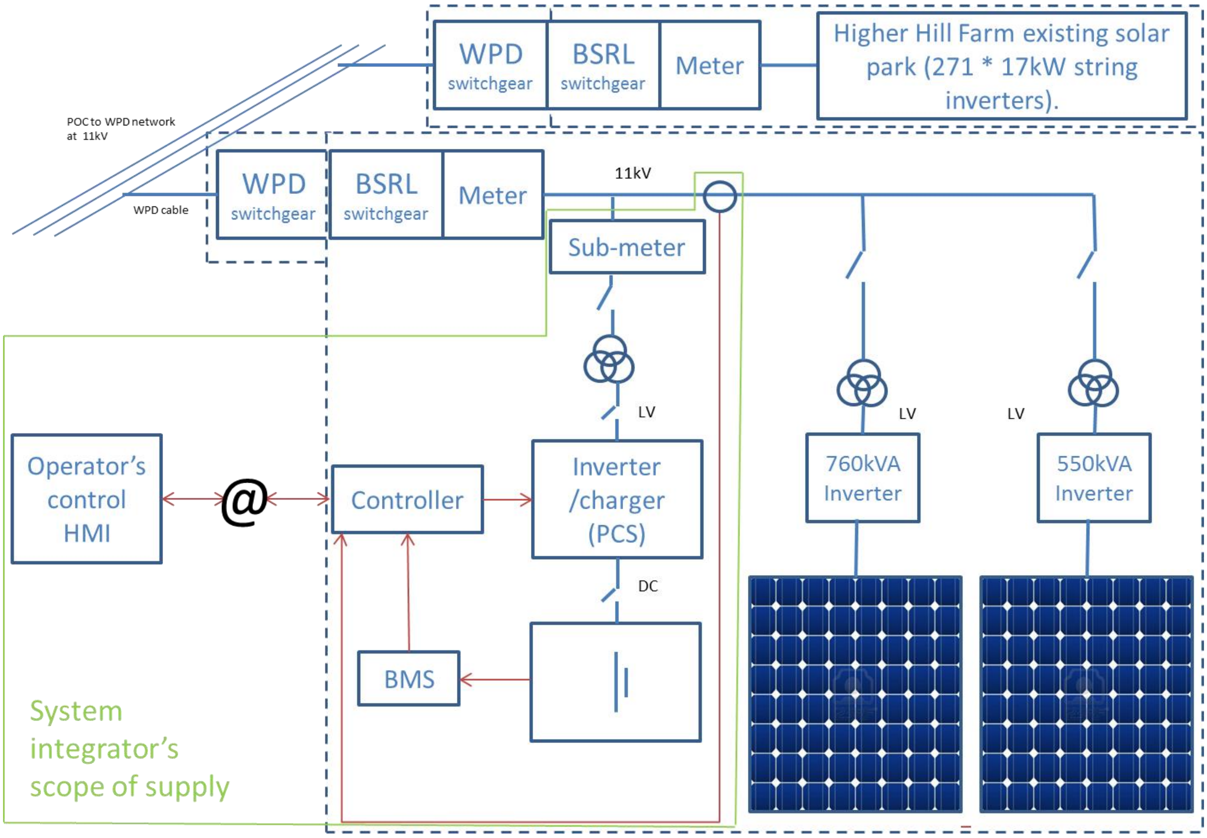
The project aims to test the nine use cases listed below where a battery can provide benefits to different parties. As well as evaluating the efficiency and efficacy of the battery at delivering the use cases, the project will also estimate the financial benefits and consider how these use cases reflect the potential for layering revenue streams. The project does not include the provision of services to National Grid, such as Enhanced Frequency Response, which is one of the major drivers of storage connections. However testing the battery to see how well it could provide such services is of interest to BSRL and will be included if time allows.

Usage Case	Beneficiary
1) Arbitrage - Sell electricity for a higher price per kWh	Owner
2) Local demand peak lopping e.g. as a service to a customer with a soft inter-trip connection who would otherwise be constrained.	DNO / load customer
3) Peak lop network demand at the local primary	DNO
4) Raise minimum demand to limit voltage rise.	DNO
5) Voltage control via reactive power.	DNO
6) Peak lop generation to enable solar parks with an installed capacity over that of the connection agreement	Owner
7) Smoothing / Power Quality.	DNO
8) Change peak lopping level (glass ceiling).	DNO
9) Multiple storage system control (To be demonstrated via modelling only)	DNO

The solar farm where the battery is installed is electrically connected to a clean 11kV feeder supplied by the Millfield primary substation. This has been altered to introduce an additional ring main unit to provide isolation between the battery and the solar farm.



Electrical connection to Higher Hill battery



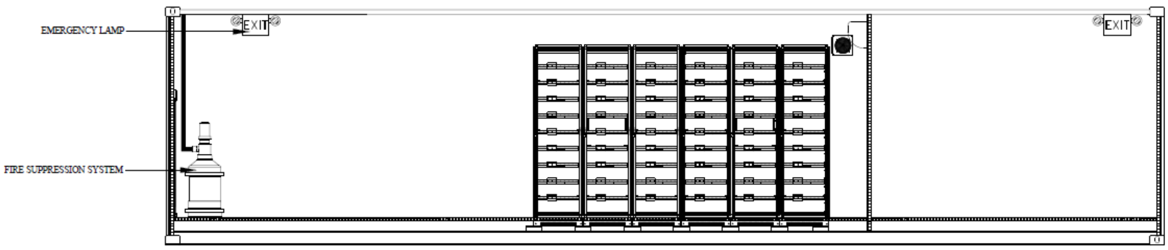
The battery is metered separately and connected via an LV isolating transformer

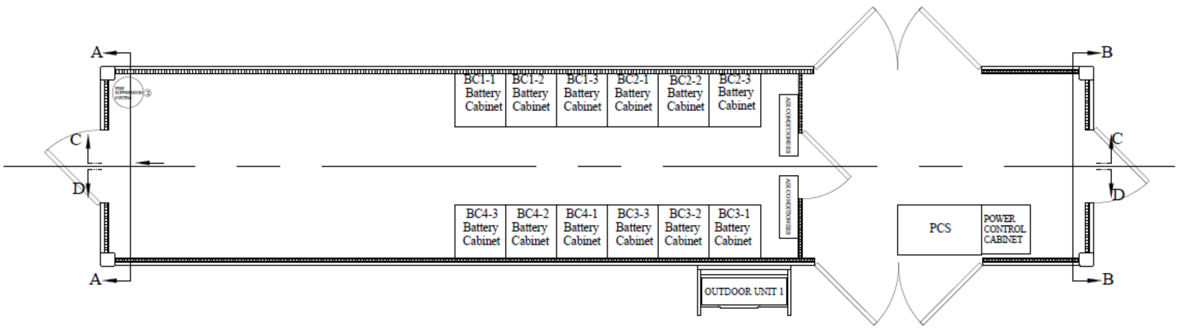
2.2.1 Design & Procurement

These activities have been completed successfully. The process of obtaining planning was relatively onerous and non-material amendments to the planning permission were required when the outline of fenced area was altered to more accurately reflect site conditions. The total area of the enclosure was reduced to allow for improved access across the BSRL site without compromising vehicle access to the battery itself.

The design sign-off was a two stage process that covered the battery itself followed by the balance of plant.

Examples of the images from the design process are given below. It can be seen that the container is divided into two compartments for safety reasons, such that the battery operator is separated from the battery itself and the fire suppression system. The drawings also show that only part of the usable space within the battery compartment is used and that it would be possible to approximately double the battery capacity if desired.





Access doors

2.2.2 Construction

Construction was completed in October 2016 with the exception of a couple of minor snagging items which have since been resolved. A separate report covering the site commissioning tests has been produced. Issues encountered during the construction phase included;

1) Location of cables differing from plans.
2) Damage to communications cables during the erection of fencing.
3) The requirement of a specialist driver to transport the battery due to its hazard rating.

The photograph shows some key stages of the construction

Battery arrival and offloading

Battery on the plinth before and after fencing

Circuit breakers and emergency stop

Resolve control panel

Battery strings and fire suppression system

2.2.3 Safety

Safety was given a high priority during construction with direct oversight and co-ordination between RES and BSRL staff. The construction was completed without injuries. While the fire risk of the installation is low, the local fire brigade have been notified of the battery's presence and consulted on safety procedures. As the battery can be operated remotely, personnel are rarely on site other than for routine inspection visits. A process has been put in place to notify battery operators if staff are expected on site.

2.2.4 Operation

The battery has been operated sporadically since its commissioning. There have been frequent interruptions to the testing schedule as a result of the battery not operating as expected and time taken to investigate and resolve the unexpected behaviour.

Issues include:

- Imbalance between the State Of Charge (SOC) of the four battery strings.
- Unexpected G59 trip that does not appear to relate to genuine events.
- Battery temperature resulting in protective overrides due to calibration issues with the air conditioning units.
- Execution of "ghost" schedules that cannot be viewed using the control software.
- Apparent sudden loss of charge.
- Apparent loss of charge while the battery is inactive at higher than expected levels.
- Erroneous alarm indication.

Of these issues, the imbalance between battery strings has been the most frequent. While the battery can be operated with a degree of imbalance between the strings, this restricts the range over which the battery can be operated. As operating the battery above or below certain SOC limits could damage the battery, and would invalidate the battery warranty, the approach taken, which is to err on the side of caution where there is uncertainty, is reasonable. The battery manufacturers BYD have suggested possible options to improve the accuracy of the state of charge estimation, such as using current transformers with a smaller range and modifying the point at which the system changes between current integration and voltage measurement as the primary input.

Despite the interruptions to testing, a set of test results were produced. However, the unstructured nature of the data and analytics relating to the testing has been problematic due to a change in staffing. The intention now is for the new structure for the data and analytics documents to be agreed, documented and validated by BRE/NSC to ensure future usability by third parties.

2.2.5 Analytics

The operational data from the battery is recorded constantly within the Resolve system and can be reviewed and downloaded using the Resolve system.
There will be an additional "backup" database provided in MS Access format that can be used to support the analysis by BSRL or could be used to support analysis by third parties.

Some initial analysis was carried out in the first set of operational data that considered the viability of arbitrage using the battery to charge overnight and discharge during the morning.

2.2.6 Process oversight / validation

The anticipated activity by BRE/ NSC has been deferred until the first set of testing has been captured and the output data stored in a structured manner.

2.2.7 Auction / Removal

The lease for the battery site expires at the end of March 2018 and requires that the land be restored to its former condition. At the time of the lease negotiation it was expected that the battery would be auctioned off and that either the battery would be bought by BSRL (in which case the removal work would not be required) or that an agreed buyer could be found in September/October 2017, with removal by the buyer planned for January/February 2018 and restoration of the site in February/March 2018. The auction would be preceded by an independent evaluation of the capacity of the battery which would confirm its function and help in the process of setting a guide price. Potential interested parties would be notified of the battery sale by WPD and would include the Energy Storage Network, other DNOs, aggregators etc.

There is a risk that the battery will not be attractive to third parties and that WPD will need to remove the battery at the end of the project.

2.2.8 Dissemination

As per section 1.6, the project has had a relatively high profile externally and has attracted interest and enquiries from third parties. Future dissemination work will depend on the availability to obtain sufficient operating data to support the analysis and learning.

3 Progress against Budget

Spend Area	Budget (£k)	Expected Spend to Date (£k)	Actual Spend to Date (£k)	Variance to expected (£k)	Variance to expected %
WPD Project Management & dissemination	143	74	77	3	4%
Project Partner Project Management	123	16	6	-10	-63%
Equipment & Installation and decommissioning	484	482	471	-11	-2%
Trials	123	16	6	-10	-63%
Specialist analysis / review	47	33	33	0	0%
TOTAL	**921**	**620**	**592**	**-28**	**-5%**

Comments around variance

The total budget is lower than the value in the PEA reflecting the actual costs for battery procurement being lower than anticipated.
The underspends on project management and trials activities relate to work which is largely complete but has not been invoiced while a minor issue remains outstanding.

4 Progress towards Success Criteria

The success criteria from the PEA are as follows

Criteria	Progress
Phases a to d below completed safely, on time and on budget. a) Complete Design of BESS. b) Procure equipment, install and commission. c) Run trials and write report. d) Identify changes necessary for participation on the Balancing Mechanism.	Items a, b and d have been completed. Item c is ongoing. Positive developments include the improvement of the control algorithm within Resolve to 1) Ensure the combined output of the battery and PV site do not exceed the connection agreement

	2) Improvement of the algorithm for PV peak lopping. Also the development of an alternative signal by BSRL to test the soft inter-trip use case which has reduced the instrumentation and communications requirements.
All usage cases are investigated and a comprehensive analysis of all data collected undertaken. Useful and applicable conclusions generated from the data analysis.	Arbitrage use case investigated and analysed, remaining use cases require more operational data.
Effective communication of the project's results and conclusions to the UK renewable energy and power distribution community.	Good progress on publicising the project itself. Progress on disseminating results is limited until results are available for dissemination.
Successful engagement with stakeholders, influencing the development of relevant governing mechanisms such as the grid code or balancing mechanism (BM).	Regulatory report shared with key stakeholders and contributed to WPD's response to the recent joint call for evidence.

5 Learning Outcomes

The majority of the learning is expected to come after more battery operational data is available, however a summary of learning points to date is given below.

Design and Procurement

- The use of a partner to assist with the procurement of the battery was essential as DNO staff are not yet sufficiently familiar enough with battery technology to carry out procurement unaided.
- Include more flexibility in the Statements of Works to avoid the significant work of re-signing.
- Having a decent level of technical detail during the procurement stage is beneficial
- The contractual conditions covering the battery operation should have included a clause concerning the imbalance between strings. It appears this is a standard clause in other battery contracts.

Construction

- Ensure that legal issues are resolved early in the construction schedule.
- Expect a degree of inaccuracy in plans.

- Power Quality monitoring was something of an afterthought to the project and procurement and installation has taken longer than expected.

Operation

- Establish a log of daily operations and issues early on.
- The process for communications and notifications is made more complex by having multiple parties involved in different countries.
- Operational issues will not always be detected during FAT and SAT testing.

Analysis

- Determine a structure for storing data early on.
- Determine conventions to ensure that variables in analysis are used consistently and can be updated centrally.

Project management

- Including contingency in both budget and schedule is essential.
- Having a structured means of managing project documentation is essential when there are staffing changes.
- It is difficult to shift focus and plan for the next stage of a project when the current stage is not progressing as planned.

Use cases

The capability of the battery to perform the majority of the use cases was demonstrated, albeit in a shortened and simplified form, during the commissioning tests.

- Arbitrage – as predicted by the techno-economic modelling, the arbitrage use case was not often seen to be profitable. Part of this relates to the contract through which the energy is sold by the PV site which is tailored to PV supplies. It may be possible to improve sales prices, however the price differential was rarely sufficient to overcome the energy losses and costs of operating the battery.

- Voltage control – the impact on voltage during the commissioning tests was seen to be very small.

- Power smoothing – the algorithm to smooth the output from the PV site was seen to be very effective, though currently the business case is less clear.

6 Intellectual Property Rights

A complete list of all background IPR from all project partners has been compiled. The IP register is reviewed on a quarterly basis. No foreground IP has been identified for this project to date.

7 Risk Management

Our risk management objectives are to:

- Ensure that risk management is clearly and consistently integrated into the project management activities and evidenced through the project documentation;
- Comply with WPDs risk management processes and any governance requirements as specified by Ofgem; and
- Anticipate and respond to changing project requirements.

These objectives will be achieved by:

- ✓ Defining the roles, responsibilities and reporting lines within the Project Delivery Team for risk management;
- ✓ Including risk management issues when writing reports and considering decisions;
- ✓ Maintaining a risk register;
- ✓ Communicating risks and ensuring suitable training and supervision is provided;
- ✓ Preparing mitigation action plans;
- ✓ Preparing contingency action plans; and
- ✓ Monitoring and updating of risks and the risk controls.

7.1 Current Risks

The Solar Storage risk register is a live document and is updated regularly. There are currently six live project related risks. Mitigation action plans are identified when raising a risk and the appropriate steps then taken to ensure risks do not become issues wherever possible. In Table 7-1**Error! Reference source not found.**, we give details of our top five current risks by category. For each of these risks, a mitigation action plan has been identified and the progress of these are tracked and reported.

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Insufficient data to determine power quality impacts	Major	Use of temporary monitor until permanent equipment is installed.	Installation of permanent equipment is expected soon
Battery operational issues prevent test schedule completion	Major	Continue to provide comprehensive information to RES and BYD and monitor availability for comparison to contractual requirements.	BYD have identified the algorithm that requires improvement for string balancing and are investigating options.
Continuous support of all partners for the duration of the project is not possible.	Moderate	Continue to emphasise the value of the project and ensure the learning is useful to all parties.	Commitment from parties is still strong despite changes in staff
Managing health and	Minor	Continuous risk	Risk is diminished now

safety risks causes delays or over spends		assessment process from project start and contingency in budget.	that construction is complete.
Potential for additional removal / storage costs if the battery cannot be sold at the end of the project	Minor	Resolving the operational issues and demonstrating the battery value.	BYD have identified the algorithm that requires improvement for string balancing and are investigating options.

Table 7-1: Top five current risks (by rating)

Table 7-2 provides a snapshot of the risk register, detailed graphically, to provide an on-going understanding of the projects' risks.

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	0	0	0	0	0
	More likely to occur than not/Likely to be near future	0	0	0	0	0
	50/50 chance of occuring /Mid to short term (11-15)	0	0	0	1	0
	Less likely to occur/Mid to long term (6-10)	0	0	0	1	0
	Very unlikely to occur/Far in the future (1-5)	1	1	1	0	1
		1. Insignificant changes, re-planning may be required	2. Small Delay, small increased cost but absorbable	3. Delay, increased cost in excess of tolerance	4. Substantial Delay, key deliverables not met, significant increase in time/cost	5. Inability to deliver, business case/objective not viable
		Impact				

	Minor	Moderate	Major	Severe	
Legend	3	1	2	0	**No of instances**
Total	6				No of live risks

Table 7-2: Graphical view of Risk Register

Table 7-3 provides an overview of the risks by category, minor, moderate, major and severe. This information is used to understand the complete risk level of the project.

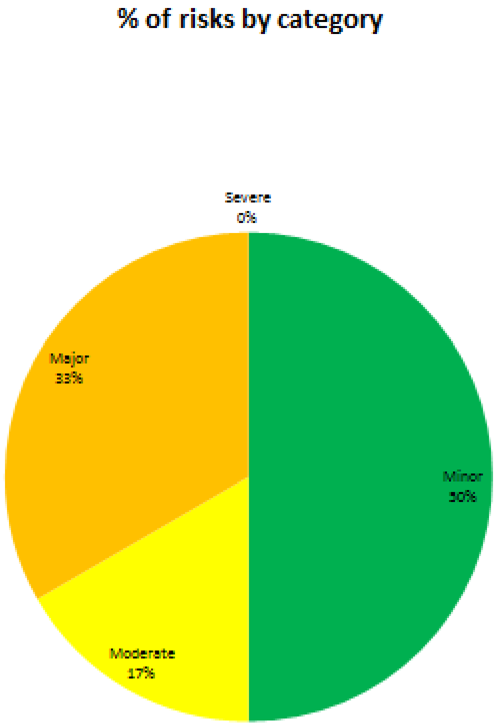


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Table 7-3: Percentage of Risk by category

7.2 Update for risks previously identified

Descriptions of the most significant risks, identified in the previous six monthly progress report are provided in

Inclement weather and/or adverse ground conditions causing long delays.	**15**	N/A	Contingency in schedule	Closed

Table 7-4 with updates on their current risk status.

Details of the Risk	Previous Risk Rating	Current Risk Rating	Mitigation Action Plan	Progress
No suitable	**36**	N/A	Industry engagement	Closed

tenders				
Proposed site is unsuitable for installation.	**30**	N/A	Alternative location identified	Closed
Unable to obtain legal consent to cover battery location	**16**	N/A	Continual engagement	Closed
Unable to provide control signal to take place of soft intertrip panel	**16**	N/A	Alternative signal device provided by BSRL	Closed
Inclement weather and/or adverse ground conditions causing long delays.	**15**	N/A	Contingency in schedule	Closed

Table 7-4: Risks identified in the previous progress report

8 Consistency with Project Registration Document

The scale, cost and timeframe of the project has remained largely consistent with the registration document, a copy of which can be found here
https://www.westernpowerinnovation.co.uk/Document-library/2016/Registration-Forms/Solar-Storage-Project-Registration-Form.aspx

There have been changes to the timescales reflecting delays in the procurement and construction phases such that the battery operation is now from October 2015 to February 2017. Additionally the cost of the battery was less than the original estimate so it is likely that the project costs will be significantly less than the budgeted value.

9 Accuracy Assurance Statement

This report has been prepared by the Solar Storage Project Manager Jenny Woodruff, reviewed and approved by the Future Networks Manager (Roger Hey).

All efforts have been made to ensure that the information contained within this report is accurate. WPD confirms that this report has been produced, reviewed and approved following our quality assurance process for external documents and reports.