Smarter Network Storage
Low Carbon Network Fund
Progress Report June 2015

UK Power Networks
Delivering your electricity

Contents

Table of Figures

1 Executive Summary

1.1 Project Background

Energy storage is a key source of flexibility that can help address some of the challenges associated with the transition to a low-carbon electricity sector. Storage, as identified by the Smart Grid Forum, is one of the key smart interventions likely to be required in the future smart grid. However, challenges in leveraging the full potential of storage on distribution networks to benefit other industry segments, and a lack of demonstrations of commercial models are currently hampering the efficient and economic uptake of storage by the electricity sector.

The Smarter Network Storage (SNS) project is carrying out a range of technical and commercial innovation to tackle these challenges and facilitate more efficient and economic adoption of storage. It is differentiated from other LCNF storage projects through the demonstration of storage applications across multiple parts of the electricity system, including the distribution network but also outside the boundaries of the distribution network. By demonstrating this multi-purpose application of 6MW/10MWh of energy storage at Leighton Buzzard primary substation, the project is exploring the capabilities and value in alternative revenue streams for storage, whilst deferring traditional network reinforcement.

The project aims to provide the industry with a greater understanding and a detailed assessment of the business case with the full economics of energy storage, helping to reduce system investment costs and accommodate increasing levels of intermittent and inflexible low carbon generation. The project was awarded funding of £13.2 million by Ofgem, under the Low Carbon Network Fund (LCNF) scheme in December 2012 and will last four years, from January 2013 to December 2016.

1.2 Summary of Progress

In this reporting period, the project has continued with integration testing of the storage system and testing of the developed software platforms. Progress has also been made with initial network and commercial trials using the system. These activities have however needed to be carried out in parallel with further investigations and troubleshooting by suppliers, as a result of the system defects raised in the previous reporting period. These have continued to cause an issue in utilising the full capacity of the storage system during this period.

The investigations carried out have now identified several mitigation solutions for these defects, although it is now evident that some of these may require some reasonably significant re-work of the electrical connection to the 11kV network and therefore require further assessment and design work to determine the best course of action. This is not expected to result in additional cost to the SNS project, but does increase the risk of further delays to the scheduled service trials.

These system issues have prevented reliable operation of the full capacity of the system during this period, and meant that all trials have not progressed as originally planned. However operation for some trials has still been perfectly feasible and a number of core commercial service and network trials have now been completed. It is expected that these delays can be recovered during the remainder of the project without loss of learning.

1.3 Risks and Issues Summary

Procurement Risks and Issues

No procurement related risks or issues have been experienced during this reporting period.

Installation and Other Risks and issues

Several of the issues highlighted in the previous reporting period have continued to have an impact during this period, and several investigations has been carried out by lead supplier, S&C Electric, involving senior product experts to analyse and identify resolutions. The key issues and risks experienced during this reporting period are summarised below:

- **EMC and Noise issues** – Following identification of the previously reported EMC emissions issues from the storage system, the on-site investigations have concluded that the main root cause is high resonant voltages being generated between the two halves of the Power Conversion System (PCS) line-up when both PCS's are operating. The resonating voltage is propagated through the battery circuits causing intermittent tripping and instability in the system output. Although all inverter units are operational, a workaround in place involves only operating one inverter in a line-up at any one time, whilst the AC-circuit breaker is open to isolate the other inverter. This in effect reduces the current usable power and energy capacity to 3MW/5MWh until a long-term solution is implemented, which still represents the largest battery energy storage capability currently operational in the UK. Several options for a long term solution have been identified, which are all likely to require some reasonable level of additional electrical installation or re-work. Further assessment of the detail and impact of these mitigations is required before selecting the optimum solution.
- **Circulating current and inductive heating issues** – High frequency circulating currents were identified at approximately 35kHz, a harmonic of the switching frequency of the power inverters and choppers, particularly when both halves of a PCS were in operation. This was causing touch potentials[1] between solidly earthed equipment, and also inducing circulating currents in the surface of the metal tray-work supporting the earth cables. These issues were successfully resolved through the installation of additional earthing conductors in February.
- **Communications interference issues** – Issues relating to CAN-BUS communications errors, as highlighted in the last reporting period, and noise on the 24VDC control power bus to the batteries have now been resolved following mitigations implemented during the supplier site visit in May.

  Risk of delays to some service trials – The above issues have caused some delays to the ongoing trial operation of the facility, and the prospect of further necessary mitigation works raises the risk of continued delays to the trial program while these works are carried out. However, this is planned to be mitigated by continuing to carry out the majority of scheduled trials with the power available from the storage system, which will provide the same level of trial learning. In this reporting period, a number of network and commercial service trials have already been completed which are described further in Section 2.1.5. The FFR service trials in particular have been postponed during this period, due to the provision for 6MW only in current commercial arrangements. However, to mitigate this it is currently being investigated with partners whether pre-qualification and service trials can be carried out with the stable 3MW currently available until a full resolution is in place, particularly in light of the new 'Bridging' arrangements published by National Grid which is intended to allow access for smaller storage and DSR units[2].
- **IBM Messaging changes** – A number of design changes to the messaging schema had to be made at the point of integrating the software components BESSM (Battery Energy Storage System Manager), FOSS (Forecasting Optimisation and Scheduling System) and KOMP (Kiwi's Operational Management Platform). These incompatibility issues slowed the testing as systems could not exchange data between them.
- **FOSS Design Changes** – During testing it became evident that there was an incorrect implementation of the recurring services behaviour and cost calculation in FOSS, requiring changes to allow flexible service windows to be scheduled and to allow optimisation to determine the best commercial service to schedule. This resulted in an extension to the SIT phase as these were significant changes to the FOSS logic.

1.4 Learning and Dissemination Summary

The SNS project continues to generate and capture key learning, which in this reporting period has predominantly materialised from the commissioning and early operation of the storage facility and through the additional work into appropriate regulatory and legal frameworks for storage.

[1] http://en.wikipedia.org/wiki/Earth_potential_rise#Step.2C_touch.2C_and_mesh_Voltage
[2] http://www2.nationalgrid.com/UK/Services/Balancing-services/Frequency-response/Firm-Frequency-Response/FFR-Bridging/#

The key learning outcomes are summarised below, with further information available in Section 7.1:

- The provision of TRIAD avoidance service is likely to form an important part of the portfolio of services for a commercial operator, which in some scenarios could cause conflicts with services to a DNO
- EMC compatibility testing and factory acceptance should be thoroughly carried out using representative layouts, connections and scales of equipment as close as possible to the 'as-installed' system
- Earthing systems appropriate for high frequency currents should be specified for future installations of building-housed storage to avoid unwanted circulating currents
- Consideration needs to be given to appropriate validation test methods for frequency response behaviour
- Control systems that have no synchronisation in the architecture at the system level may cause small fluctuations in power output, if they choose to optimise power delivery amongst inverters
- Relatively simple parts of the overall solution can become single points of failure that could have a significant effect on network support operations or commercial services. Redundancy and resilience should be considered at all sub-system and IT levels

To ensure that the project is continually capturing learning resulting from the project, workshops involving the project team are scheduled, outside of other governance and project meetings, which provides a forum for specifically discussing and capturing new learning.

In addition, the partner forum, which was held on 14 May, provided an opportunity to discuss and capture any additional learning with external project partners.

Internal dissemination, project–related events, external communications and engagement carried out during this period include the following activities. A full list and further detail is available in Section 7.2:

- Article in 'Wired', the internal company magazine which is distributed to all employees
- Presentation at the UK Power Networks Live Linesman Conference
- ESOF Good Practice Guide Launch Event (Jan 2015);
- Presentation at Electricity Storage network Annual Symposium (Jan 2015);
- ESOF Meeting & SNS Tour & Dissemination Event, hosted at Leighton Buzzard
- Feature on BBC Radio 4 Today Programme (March 2015)
- Contribution to Carbon Trust TINA refresh and project Knowledge Exchange (March 2015);
- Contributions to Parliamentary Briefing POST note on Energy Storage (March – April 2015);
- Presentation at Large Scale Solar UK Conference, Bristol (April 2015);
- Newcastle University Academic Paper - Probabilistic Sizing of Electrical Energy Storage for Demand Peak Shaving with Static and Real-Time Thermal Ratings; D. Greenwood, P. Taylor, N.S. Wade (April 2015) Submitted to IEEE Transactions on Sustainable Energy
- SNS Tour and Dissemination Event for Citi University Postgraduate Students (April 2015);
- SNS Tour and Dissemination Event for Belectric & National Grid (April 2015);
- Presentation at IET Storage Event – "What's next for the grid?", London (June 2015);
- Participation in a high-level roundtable organised by the Director General of Energy for the European Commission, entitled Strategic Contribution of Energy Storage to Energy Security and Internal Energy Markets'
- Meeting held with the Institution of Civil Engineers to help inform their policy formulation for storage. (May 2015)
- CIRED Conference Paper: Scheduling power and energy resources in the Smarter Network Storage project, Newcastle University (June 2015);
- Contribution to CIRED Conference - Roundtable Participation (June 2015)

No specific local community communications and engagement has been carried out during this period, following the completion of the construction and landscaping of the installation.

2 Project Manager's Report

This section describes the progress made on the SNS project in the reporting period January 2015 through to June 2015, including the key milestones and deliverables met, any issues encountered, and provides an outlook into the next reporting period through to December 2015.

2.1 Progress in the reporting period

2.1.1 Project resourcing and governance

2.1.1.1 Project Resourcing

The project team remains mainly unchanged since the last reporting period, and has continued to leverage expertise in the close down and completion of civil and electrical snagging from UK Power Networks' Capital Programme Directorate, and our appointed Principal Contractor; Morrison Utility Services. Resource for the ongoing investigations and defect resolution of the storage system are predominantly provided by S&C Electric and Younicos.

Minor changes include the reallocation of Senior Responsible Owner of the project to Suleman Ali, Director of Strategy & Regulation, following the departure of Ben Wilson, Director of Strategy & Regulation & CFO, from UK Power Networks. In addition, support for dissemination and communications has been reallocated to a central Stakeholder Engagement team.

The following organisation chart, in Figure 1, shows all the allocated resources within the SNS project structure as of May 2015.

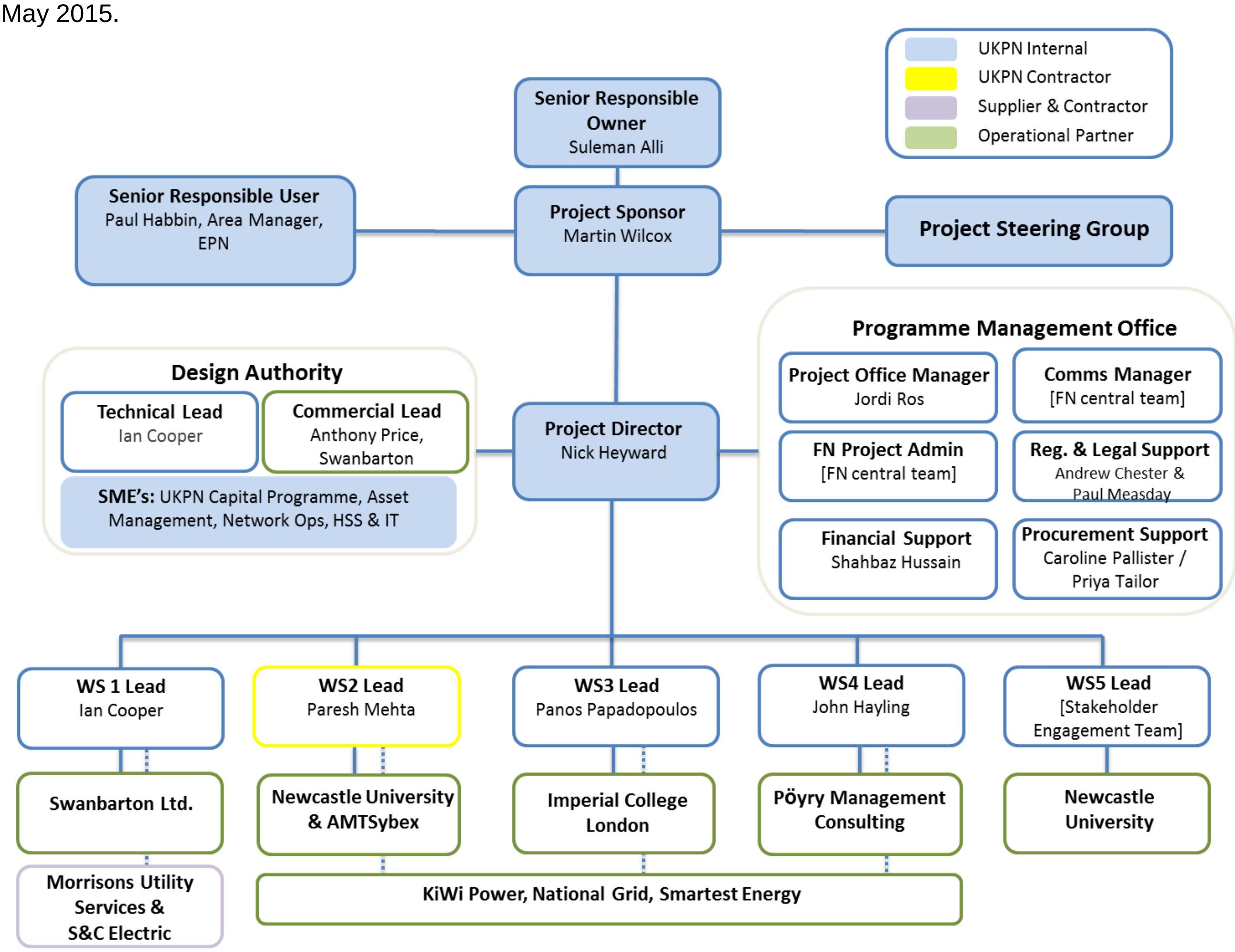

Figure 1: Smarter Network Storage organisation chart

Engagement continues with the core project partners both through ongoing work, and at a more senior level through the Partner Forums. The last Partner Forum meeting was held on 14 May and provided a recap of the project progress against objectives, a look ahead to upcoming activities. As usual, an opportunity was also provided for partners to feedback any learning and feedback, share their own storage-related updates, and a discussion held to generate ideas for learning and dissemination.

2.1.1.2 Project Governance

The governance model, as described in the previous six month progress report, is unchanged, with the exception of the involvement of Barry Hatton (the Director of Asset Management) in Steering Group meetings, and continues to be operated by the Programme Management Office. The model identifies two distinct streams: Solution Governance and Project Governance and helps to ensure a focus on developing effective technical and commercial solutions to meet learning outcomes, as well as an effective structure for ensuring the overall solution is delivered on time, to budget and to the appropriate quality.

Further information on this governance model, including supporting project control and reporting mechanisms, is documented in the SNS Project Handbook (SNS5.4).

Key Issues Encountered

No significant issues have been encountered in this area during the reporting period.

Key Deliverables

No new deliverables have been developed in this area during the reporting period.

2.1.2 Project Planning

As highlighted in the previous six-month progress report, a number of issues that arose during the commissioning and testing phase required additional investigations, tests and mitigation works by the storage supplier on the energy storage device which has delayed the start of the full system integration testing and service trials.

During this reporting period, a number of mitigations have now been installed that have resolved some of these issues, and further supplier investigations have been necessary to continue to identify root causes and potential methods of resolving the remaining defects as described further in Section 2.1.3. As such, this has required additional time to be scheduled to allow for these works to take place which has limited the ability to make progress of some service trials.

More frequent progress reviews and workstream-level project planning has therefore continued throughout this current reporting period to ensure progress is closely monitored and plans updated accordingly. A summary of the high level activities and status is shown below for the period November 2014 – February 2016.

This has required the project to re-phase various dependent activities, most notably the commercial frequency response trials. However, progress has still been possible in other trial areas, including STOR and network based trials which are described further in Section 2.1.5. At this stage it is not anticipated that the level of learning generated from trials or subsequent key milestones will be affected due to the ability to carry out further trials this year and in conjunction with the optimised and integrated trial stage throughout the final year of the project.

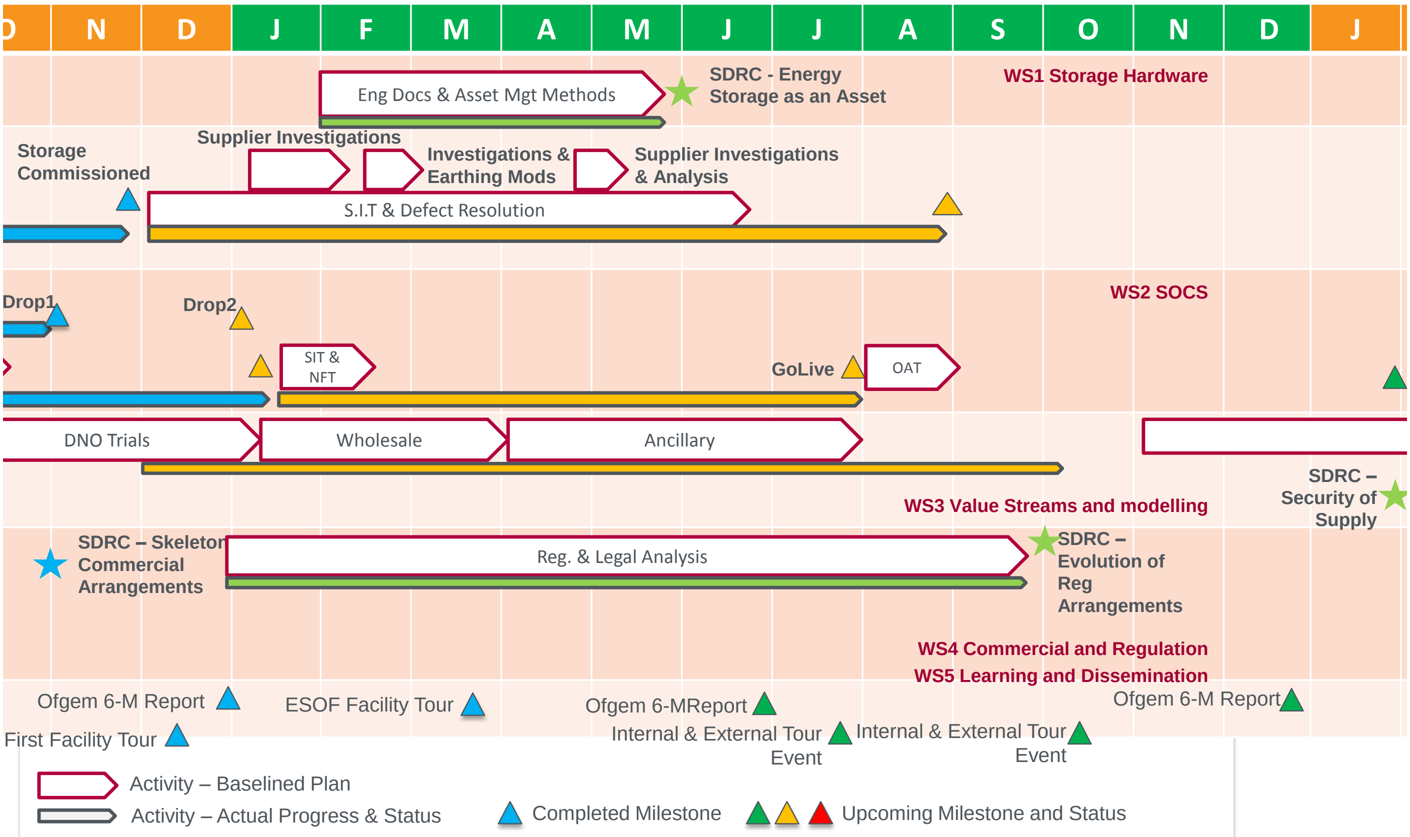

Figure 2: High level timeline

Key Issues Encountered

No significant issues have been encountered related to planning during the reporting period.

Key Deliverables

No new deliverables have been developed in this area during the reporting period.

2.1.3 WS 1 – Energy Storage Hardware

The focus within this reporting period has been the testing of the energy storage system. Detailed preparations have been made for the operation of the system including the preparation of user guides and training materials; delivered to UK Power Networks staff in the local area as well as to network control engineers and other relevant staff.

2.1.3.1 Planning, design and construction

The previous reporting period included the completion of the construction work at Leighton Buzzard and the planting of the landscaping scheme around the site. During this reporting period the focus from the construction side has been the rectification of any defects identified by the UK Power Networks Construction Assurance Supervisor to enable the close out of the construction phase.

This included some internal and external items, exemplified by the following:

- To reduce the voltage drop on the 110V DC supply to the SNS building the cores on the cable used were required to be “doubled up” increasing the cable cross-sectional area (SNS_DN_SM1-2);

- One additional earth pin to be installed along each of the two longer sides of the weldmesh fence (SNS_DN_SM1-3);
- The planted vegetation required some attention: as some plants subsequently died following planting, others required better staking and some required re-planting (SNS_DN_SM1-5);
- Several external doors stuck on the frames, requiring excessive force to open (SNS_DN_SM1-7);
- Since the start of spring the planted vegetation has been growing vigorously including the grassed area leased to Central Bedfordshire Council (CBC). This area now becomes the responsibility of CBC to maintain, using the contributions provided through the Section 106 agreement completed in 2013. As described above some of the vegetation has died which will be replaced by UK Power Networks' contractor, as required by the planning conditions. Members of the public have been witnessed using the new footpath created between the substation side and Clipstone Brook, as well as using the grassed area for dog walking.

Figure 3: Photo showing the land leased to Central Bedfordshire Council for public use

2.1.3.2 Testing

The testing in this reporting period continued from the completion of the commissioning of the Energy Storage Device (ESD) late in the last period into systems integration and defect rectification. The detail of the efforts integrating FOSS with BESSM is discussed Section 2.1.4 below whereas the content here describes the integration with the UK Power Networks control system and defect resolution.

At the completion of commissioning it was observed that there were some significant circulating currents in the installation, particularly when both 1MW halves of a PCS were in operation. This was discovered because it was observed that certain elements of the cable support structures were increasing in temperature, where no current should have been flowing. This was investigated during January 2015 and additional earth conductor was installed.

There was significant ongoing instability of the CAN-BUS communications system with some failures being identified as the re-starting of the string BMS controller, seemingly made worse by the earthing improvements. This led to further investigations of the 24V auxiliary power supplies in February 2015. It was shown that although the supply voltage was steady there were significant "spikes" while the main power inverters were running. A high impedance connection was identified in early March 2015 between one of the power supply rails and ground. Removing this caused further instability of the system with reliable operation only with 4MW of the total 6MW capability.

Measurements of the 24V auxiliary supply while in operation showed that although the $^{+}$ve to $^{-}$ve voltage was very steady, both rails were moving with respect to ground. The "spikes" above occur when each rail moves differently with respect to ground. Further testing carried out by the equipment manufacturers showed that this was being caused by harmonics or noise oscillations of the main DC bus connecting the inverters to the batteries. These oscillations were being coupled through the battery components; most likely the string battery management system and rack-switchgear (BMS) and tray controllers.

Investigations by the supplier during May 2015 discovered that the removal of EMC suppression capacitors from the AC section of the PCS reduced the magnitude of the harmonics and noise oscillations on the DC side of the PCS. It was also identified that there was interaction between the two 1MW halves of the PCS and batteries connected to either side. As such operation with only half (1MW) of each PCS connected was entirely stable.

At time of writing this report, a mitigation has been identified which involves separating the two halves of the PCS units, but investigations are ongoing as to what the best and most cost effective solution is to enable the full operation of each PCS without re-introducing any of the defects resolved above.

2.1.3.3 Health & safety

During this reporting period, in the defect rectification work or site tests and trials, there have been no health and safety incidents. Shortly after publishing the previous report there were plant failures of both an inverter and a battery.

In December there was a failure of the C phase power electronics tray of the right hand side of the third inverter (PCS3R). No-one was present when this occurred but the failure was contained within the PCS, the fire detection system detected that combustion had occurred, but there was insufficient fire to trigger the fire suppressant release. A detailed investigation showed that an IGBT[3] had failed on the tray but due to the damage it was not possible to determine the root cause. All the power electronics trays in that inverter were replaced as per S&C Electric's standard procedure and the inverter re-tested and returned to service early in this reporting period.

There was also a failure of a battery tray which triggered the operation of earth fault protection. Investigations showed that there had been a short circuit between the frame of a battery tray (at earth potential) and the casing of one of the battery cells (at battery terminal potential). This had caused external damage to the cell, but the cell maintained its charge. Detailed investigations by Samsung SDI confirmed that the fault had not originated within the cell itself.

The training associated with the ESD is described in the SDRC9.4 report published in this reporting period. Initial training was carried out during the previous period for the operation engineers in the local area, such that they are familiar with the new equipment and the changes carried out at the Leighton Buzzard site. In this period training has been carried out with many of the network control engineers who control the network including the ESD and have responsibility for the operation of the network. Further training sessions will be carried out into the next reporting period to ensure that all relevant staff receives the training.

Key Issues Encountered

Harmonics and EMC issues

The harmonics and EMC issue were discussed in the previous progress report and are also discussed in the SDRC 9.4 Energy Storage as an Asset published in this reporting period. This defect has caused a six week delay, up to the completion of the commissioning and Site Acceptance Tests for the ESD. The further rectification of defects, including further investigations and analysis into this one, is still in progress at the time of writing this report.

As described above some of the actions taken to resolve other issues identified have led to this issue getting worse, rather than better, but certainly the understanding of the cause and potential mitigations has greatly increased. The issues observed were that there were errors in the CAN-BUS communications between the battery string controllers and the Battery Energy Storage Device Management (BESDM) PLCs causing the BESDMs to have to switch out for safety reasons. The reasoning employed in the investigation and results from each stage are as follows:

- There were communication failures on the CAN-BUS;

[3] http://en.wikipedia.org/wiki/Insulated-gate_bipolar_transistor

- Some of this was due to noise on the bus, some due to periods of “zero response” from the battery string controllers of coincident duration to their re-start times;
- This triggered investigation of the 24V DC supply showing that there were a lot of spikes on this, further measurements and the removal of an erroneous “loose” earth showed this to be common mode noise;
- Isolating sections of the PSU cabling and load/supplies showed this was coming from the battery units, via the tray control PCBs or battery string controller PCBs. Detailed investigations showed that the AC isolation between sections on these board was not perhaps as good as it could be, although this was not a root cause of the problems;
- The noise on the main DC bus was caused by the PCSs. As this product has been in successful operation elsewhere, the recent design changes or application specifics were investigated and this identified that some circuitry added to reduce the AC side EM noise was making the DC side noise worse. This was removed; and
- Each 1MW half of a PCS was operated independently making a significant improvement, allowing stable operation.

It is likely that the electrical characteristics of the combined 2MW PCS with the batteries connected form the root cause of these problems. At time of writing this report, investigations are ongoing as to the best and most cost effective solution is to enable the full operation of each PCS without re-introducing any of the defects resolved above.

Circulating current and inductive heating

Circulating current flow was discovered at approximately 35kHz, a harmonic of the switching frequency of the power inverters and choppers, particularly when both halves of a PCS were in operation. What was not anticipated was that at this frequency skin effect[4] has a significant effect, and so points that were both solidly earthed together were measured to have touch potentials of 45V to 50V. This high frequency current was also inducing circulating currents in the surface of the metal tray-work supporting the earth cables, as shown in Figure 4, causing an increase in temperature in the metal.

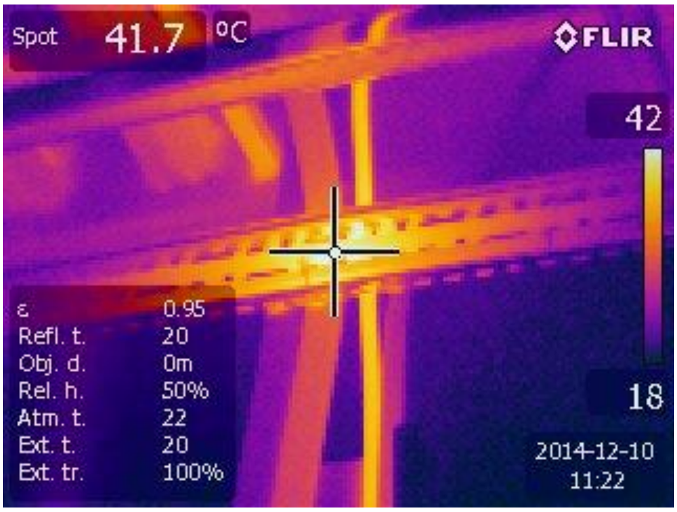

Figure 4: Picture showing temperature differential caused by induction heating in a cable support

Based on measurements of the circulating current flow taken during investigations in January 2015 the optimum size for the equipment earth conductor was calculated. This additional earth conductor was installed during February 2015 between the equipment and the building earth system and additional building earths were installed to provide as short as possible a route for the current flow to ground which fully mitigated this defect.

[4] http://en.wikipedia.org/wiki/Skin_effect

Network data measurement and communications

Late in the previous reporting period and early into this period the integration between BESSM and the UK Power Networks control system was carried out. Due to the architecture of the UK Power Networks control system it was not possible to test the alignment and functionality of all the 190 digital and analogue data points data points directly in the test environment, so many were not tested from the RTU to the control system until the SAT phase.

This identified defects specifically in the analogue scaling where there was an offset between the control system values and the RTU values. Had the control system been available in the earlier tests these defects would have been eliminated. The UK Power Networks default practice involves changes made on the control system being then rolled down to the RTU. To do this in reverse (essentially configure the RTU first) effectively doubled the work involved. Overall this did not delay the operation of the ESD, but resulted in a greater amount of effort over a longer period than was originally forecast.

There were also issues with the rate at which network data could be made available to BESSM via the RTU. Specifically the power realised at the meter position for the ESD and the total load on the Leighton Buzzard 33/11kV substation are used by BESSM to form closed loop control with its power output. The RTU had been designed to transmit data for monitoring purposes to the control system, as such speed of response was not a key design parameter. This led to a lag of one second or more between the ESD output changing and the response being available to BESSM. This is the limiting factor on the response time of the ESD in some situations, and raises a potential risk that the speed of response of the system may not be sufficient for extremely fast network services (e.g. inertia/ultra-fast frequency response) that may be developed in the future.

Awareness of these issues from the start of the project would have meant that the appropriate time and cost could be included in the project planning, even if the issues could not be eliminated. With hindsight additional measurement equipment may have been installed for the time critical network data items to ensure that optimum response is realised.

Battery string fuse nuisance operation

During the design phase of the project the battery manufacturer, Samsung SDI, requested to reduce the rating of the protection fuses installed in each of the battery strings. This held several potential advantages but primarily it would ensure that any fault causing current flow from a battery string would be isolated more quickly, improving safety. This was reviewed and recommended by S&C Electric and approved by UK Power Networks.

It became evident during the testing that multiple “false tripping” events were occurring so the situation was investigated. The review of the design change had not taken into consideration the fact that the DC side capacitors in the PCS were charged from the batteries, causing a significant inrush current. S&C Electric calculated that with a minimum of five battery strings connected the current draw from each would not be sufficiently large to cause the fuses to blow. The control system operation was updated by Younicos accordingly. S&C Electric have since made modifications to their PCS to pre-charge these capacitors from the AC side, thus allowing a single battery string to be connected an charged/discharged if required.

Key Deliverables

- **SNS1.10 –** Inspection and Maintenance Procedures for Storage
- **SNS1.11 –** SDRC 9.4 Energy Storage as an Asset Learning Report
- **SNS1.12 –** SDRC 9.4 Energy Storage as an Asset Evidence Report

2.1.4 WS 2 – Smart Optimisation & Control Systems (SOCS)

WS 2 is responsible for managing the design, development, testing, integration and deployment of the end to end IT solution; Smart Optimisation and Control System (SOCS). This platform will manage the shared-use of the storage across multiple applications, whilst ensuring network security is maintained. The SOCS solution comprises two distinct sub-systems, the software hosted within UK Power Networks' corporate IT environment, called the Forecasting, Optimisation and Scheduling System (FOSS), delivered by AMT-SYBEX, and the control software co-located with the storage at site, called the Energy Storage System (ESS), delivered by Younicos on behalf of S&C Electric.

Progress Against Plan

During this period WS 2 entered into the software integration and user acceptance phase in readiness for trials.

SOCS comprises a number of integrated software components as follows:

- **FOSS** – built on AMT-Sybex's various Affinity Suite modules. A screen shot of the services calendar view is shown in
- Figure **5**;
- **ESS** – developed by Younicos and S&C Electric on a Zenon SCADA platform. ESS consists of the following functional composition:
  - BESSM
  - BESDM
  - Storage Management System (SMS)
- **ENMAC** – UK Power Networks' Network Management System including Remote Terminal Unit RTU
- **PI** – UK Power Networks' data warehouse
- **Enterprise Service Bus (ESB)** – UK Power Networks' IBM Message Broker ESB (WebsphereMQ)

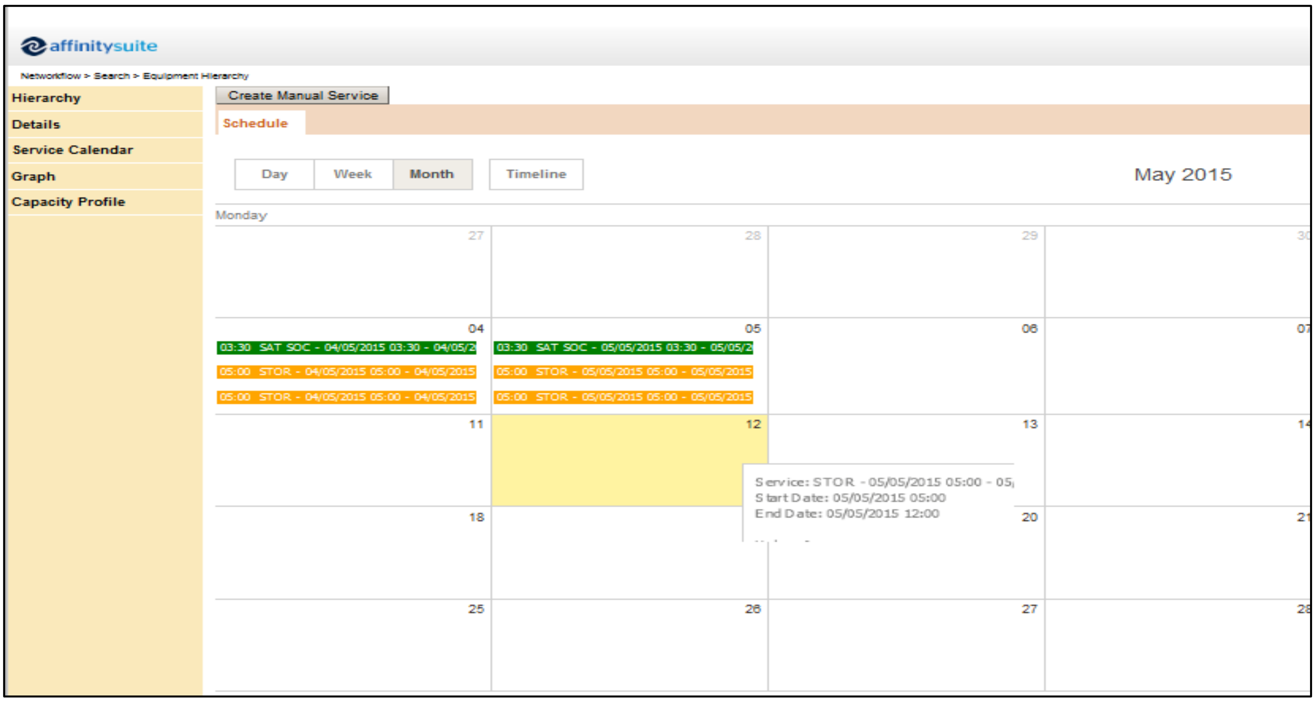

Figure 5: FOSS Calendar View

As part of the system integration plan, the ESS was integrated and tested by first connecting it the to the storage device at Leighton Buzzard. Following this, the UK Power Networks control systems were integrated with ESS. Independently the interface with third party software, KOMP, with FOSS and ESS was tested.
During this reporting period the objective was to fully integrate SOCS as shown in Figure 6 below. FOSS SAT, which was in progress during last reporting period, was successfully completed using the pre-production environment. The SAT results were validated against the forecasting and optimisation models generated by Newcastle University. Although tested in a standalone mode, it was decide not to activate the regular scheduling function from FOSS to BESSM, to allow more specific tests and trials to be more easily configured using a manual mode during the commissioning phase.

In parallel, all the data networks were made available in readiness for commissioning of the solution at Leighton Buzzard, these included the SCADA, support, human-machine-interface (HMI), ESB and security connections (see Figure 6 for different colours for each connection). Younicos and S&C Electric teams installed and integrated the ESS system with the storage device and with the Leighton Buzzard RTU. A number of functional and operational tests were carried out to prove the desired functionality and allow sign off of the commissioning phase.

Once commissioning was completed, as part of Site Integration Testing (SIT), it was planned to fully operate the storage device daily using all different combinations of modes and parameters. Twice daily conference calls were set up; the morning call to analyse overnight run's results and the afternoon call to plan the next overnight run. These manually defined schedules (not generated from FOSS) for the battery's overnight operations were executed daily (including weekends) for a period of two months. During this period the main service types were tested including Peak Shaving, Frequency Response (SFFR, DFFR), STOR and state of charge recovery. As a result, this of, this extensive testing highlighted a number of important defects that needed to be resolved including:

- Identifying and resolving incorrect FFR droop behaviour;
- Identifying and resolving 'pre-determined duration' parameter implementation for modes reflecting peak shaving, FFR and STOR services;
- Testing of different BESDM device combinations aided with troubleshooting some stability issues and CAN-Communication errors; and
- Identifying the PCS instability with regards the 24V DC supply noise.

As part of SIT at Leighton Buzzard the following software tests were successfully conducted:

- BESSM integration with ESB host to communicate with Kiwi's control room (KOMP) for STOR services start/stop signals;
- BESSM HMI for monitoring and control purposes;
- End to end testing of digital, analogue and alerting signals between BESSM – RTU – ENMAC and PI – this proved the main SCADA monitoring points required for the storage system. However, some discrepancies between scaling of data points between the RTU and the ENMAC control system are still present, and scheduled to be rectified during the next reporting period; and
- Younicos' remote access to the BESSM and BESDM devices for – (a) support (b) maintenance and (c) software upgrade purposes.

In parallel, the FOSS application followed a similar SIT pattern and the following tests were conducted:

- FOSS integration with PI for Long term forecasting;
- FOSS sending messages to KOMP via the ESB to confirm STOR contracts;
- FOSS using the web service to collect weather data; and
- The user Interface to (a) set up and configure, (b) operate, and (c) maintaining pricing and services data within FOSS.

Also tested, however not activated fully, is sending of the optimised day ahead schedule from FOSS to BESSM via the ESB and in return BESSM sending the battery status and mode of operation validations. This function will be activated once the project moves into the full Optimised Trials phase, thus reaching a fully integrated SOCS.

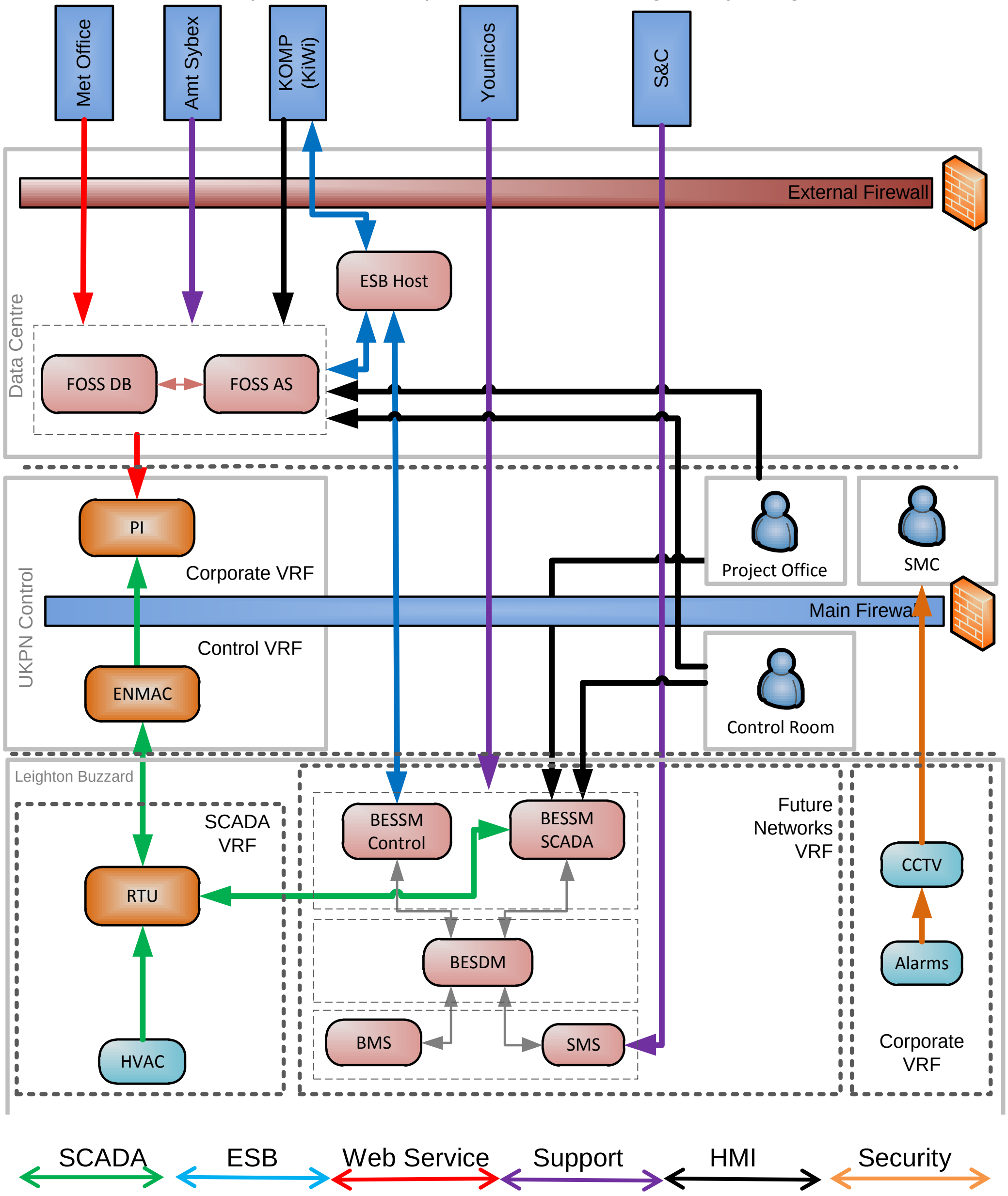

Figure 6: SOCS Data Connectivity

Throughout the commissioning and SIT phases, once a week defect analysis triage meetings were held with each software supplier to:

- Agree and adjust the defect priorities;
- Define Scope and agree date for the next release;
- Confirm defects resolved and ready for testing;
- Clarify defect details or walk through steps to recreate defect; and
- Agree if a defect or an observation should be raised as a change request. (seven CRs have been raised so far).

Table 1 shows the summary of defects identified and fixed for this project.

Application	Phase	Total Defects Identified	Closed Defects
FOSS	Defects identified during FAT1 & FAT2 (FAT2 was introduced as number of FAT1 defects resulted in retesting)	High(9) Medium(14) Low(4)	High (5) Medium (2) Low (0)
FOSS	Defects identified during SAT	High(3) Medium(12) Low(13)	High (2) Medium (12) Low (10)
FOSS	Defects identified during SIT	High(15) Medium(11) Low(14)	High (13) Medium (6) Low (10)
ESS	Open Defects from System Test into FAT	High(1) Medium(10) Low(4)	High(1) Medium(9) Low(4)
ESS	Defects identified during FAT	High(24) Medium(18) Low(9)	High (23) Medium (18) Low (8)
ESS	Defects identified during SAT	High(2) Medium(0) Low(0)	High (1) Medium (0) Low (0)
ESS	Defects identified during SIT	High(10) Medium(6) Low(1)	High (6) Medium (4) Low (1)
Leighton Buzzard	Defects identified during Commissioning	High(19) Medium(30) Low(10)	High (18) Medium (26) Low (8)

Table 1: Test defect summary

Key Issues Encountered

- **IBM messaging XML formats** – interfaces between BESSM and KOMP (KiWi control) could only be tested once the system was fully commissioned. At this point, it was observed that some aspects of the XML messaging formats were incompatible, thus resulting in a minor design change impacting changes to BESSM software. Every retest took a significant time as it involved coordinating resources across Europe. Following the compatibility change to the XML definitions, it was identified by Kiwi Power that the KOMP system required the contracted power value for commercial services and thus resulting another XML change. This later change impacted both FOSS and BESSM.
- **IBM messaging queue management** – as FOSS and BESSM are not fully integrated at all times, the messaging queues were getting full with 'Current Control State' messages sent by BESSM to FOSS. These messages were manually archived; however, when FOSS was integrated with the IBM messaging, it transpired that it could cope with the volume of status messages sent by BESSM. Thus a design change was agreed to only send messages when BESSM current state changed, thus reducing the message volume.
- **Integration of BESDM with the Storage device** – due to the storage hardware defects and communications issues, described in Section 2.1.3, some of the software testing could not be progress until the 'show stopping' defects like electrical and communication faults were fixed. Hence the SIT time table had to be extended to accommodate for these dependencies to be fixed.

- **FOSS system is based on calendar days** – this causes challenges in accommodating flexible services – recurring services where the service window spans over midnight were found to cause issues with the optimisation as the service window calculations were incorrect. This was an unforeseen design issue which took some iteration of retests to figure out the cause.
- **FOSS design for price calculation** – the pricing calculation to determine the best commercial service to be scheduled was revised and made more accurate. This was agreed with the supplier AMT-Sybex as a design change, hence involved an additional cost of £10,260. This cost was able to be absorbed within existing budget of the funded costs for WS2.
- **Short term forecasting** – the activation of short-term forecasting has been dependent on an appropriate database query definition, to allow recent demand data to be ready by FOSS. This has been delayed due to lack of appropriate resource, and so testing of this aspect of the system has been delayed.

Key Deliverables

- **SNS0.4 – Overall Solution Acceptance Report** – this report is work in progress and specifies the test completed and the status of the system in being ready for trials and BAU support.
- **SNS2.10 – SOCS Training** – Training provided to control engineers
- **Testing results** – Signed Exit reports for critical test phases like FAT

2.1.5 WS 3 – Storage Value Streams, Services and Modelling

WS 3 predominantly covers the activities relating to the operational phase of the project, including the design and execution of the range of trials to demonstrate the storage capability across a range of distribution network, ancillary and wholesale services.

Progress Against Plan

In this reporting period, a number of pre-trial tests have been completed and progress has been successfully made in carrying out DNO and TSO trials. Due to the unforeseen issues that compromised stable operation of full 6MW capability, as detailed in Section 2.1.3, a number of tests and DNO trials have been postponed to the next reporting period. The rationale behind this internal change (that is not anticipated to affect delivery of SDRCs 9.6 and 9.7), was to ensure that the peak shaving functionality existed to support the network if needed during the winter and spring seasons of 2014-2015, while dedicating the remaining available time in testing and trialling services that do not require full 6MW power output capability. **Error! Reference source not found.** shows the high level WS3 plan and the progress until this reporting period.

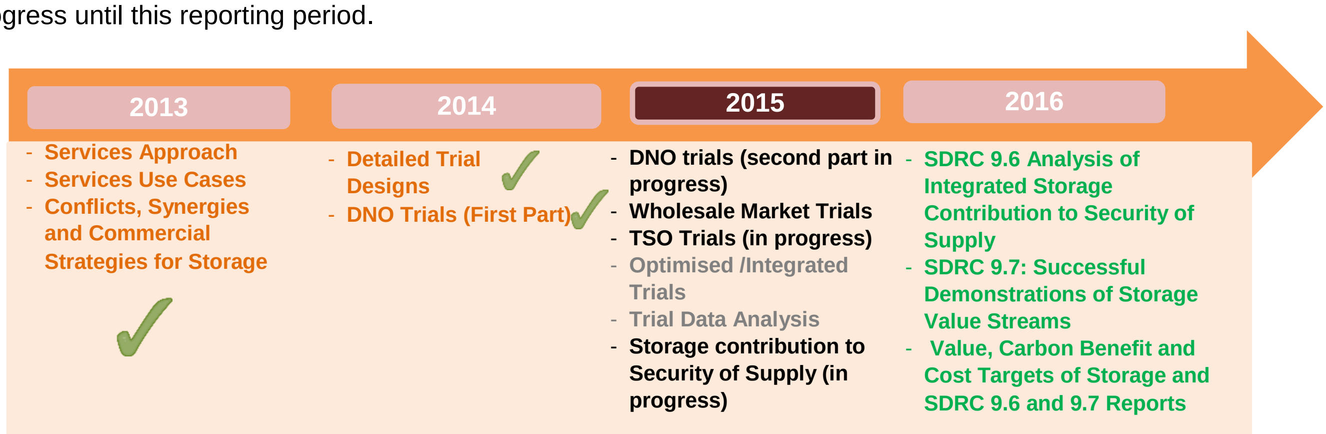

Figure 7: High Level Deliverables of WS 3 during the Project Lifecycle

2.1.5.1 DNO Trials

The peak shaving tests that were conducted during this reporting period, provided confidence in delivering network support for security of supply. 24 days with deviations over firm capacity were experienced during winter and spring seasons of 2015, however the storage was not dispatched as no N-1 events were realised. Figure 8 shows the ability of the ESS to provide peak shaving; in this particular test conducted on 10 March 2015, the loading limit of the substation was set to 28.5MVA. From approximately 17:30 to 19:17, the ESS was continuously dispatched with both active and reactive power to limit the substation loading to 28.5MVA that would otherwise exceed 30MVA.

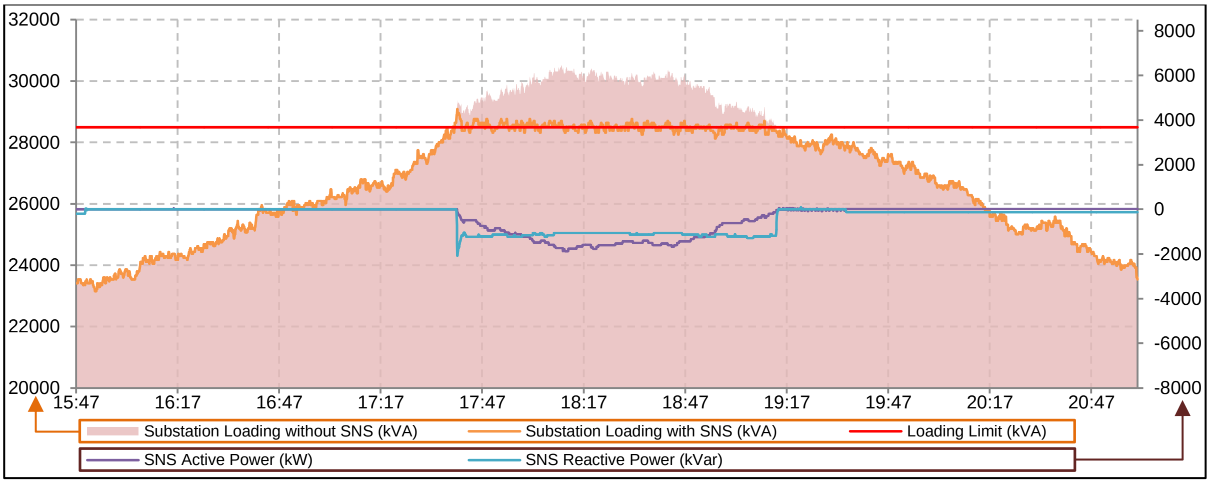

Figure 8: Peak Shaving Test using Active and Reactive Power Dispatch from the ESS with Apparent Power Threshold set to 28.5MVA

Figure 9 shows the ability of the ESS to provide peak shaving; in the test conducted on 24 April 2015, the loading limit of the substation was artificially set to 18.5MVA and the reactive power limit was set to 0 to improve the power factor at the substation level. The ESS was continuously dispatched using both active and reactive power to minimise the reactive power at the substation level but also limit the substation loading to 18.5MVA that would otherwise reach 20MVA.

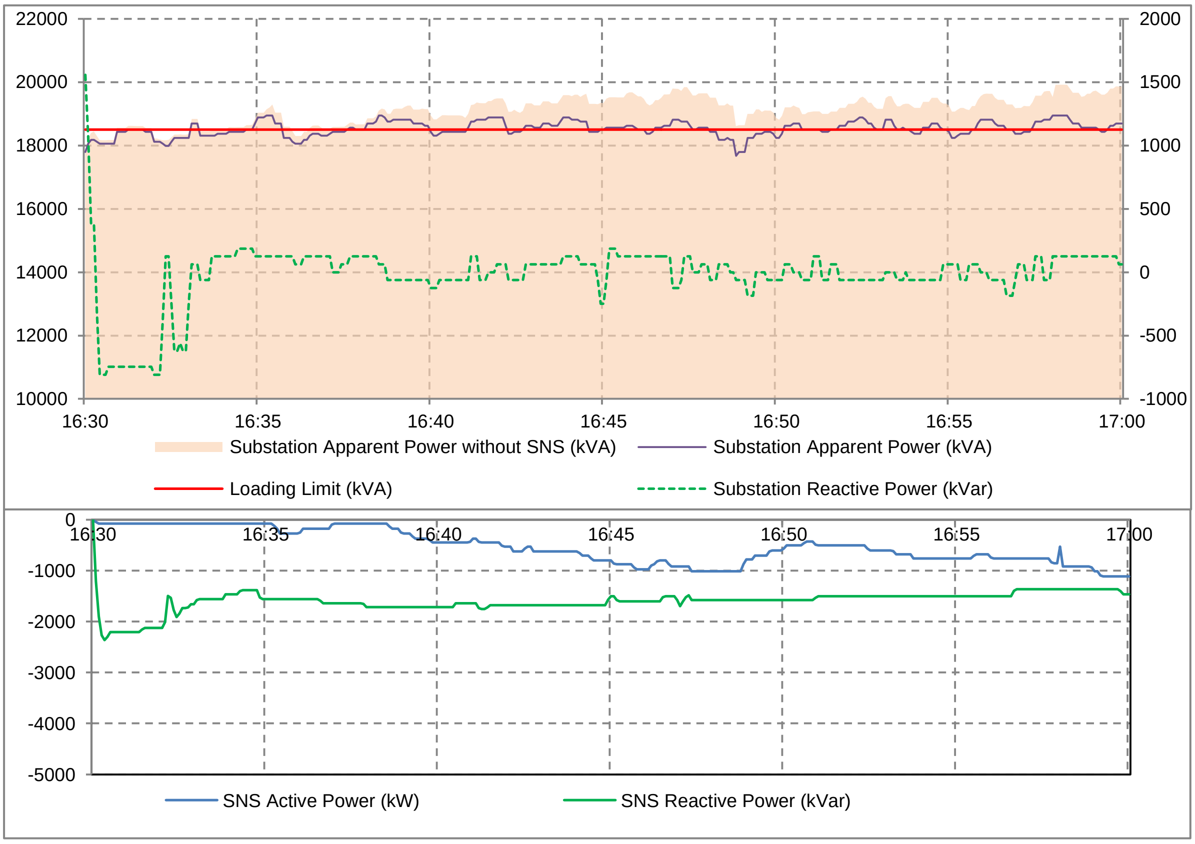

Figure 9: Peak Shaving Test using both Active and Reactive Power Dispatch from the ESS

2.1.5.2 Ancillary Services (TSO) Trials

The frequency response functionality of the frequency response mode was tested and successfully proven the service requirements (i.e. deliver response according to a pre-defined droop characteristic within 2 seconds). Figure 10 shows the results of the successful test conducted in 25 March 2015; it is shown that the active power dispatch follows the grid frequency trend during times that grid frequency exceeds the pre-defined threshold of ±0.05Hz which is modelled as dead-band in the control algorithm of the BESSM. However, although the mode behaviour has been proven, in line with contractual terms the formal qualification tests required the full 6MW available, and hence due to the current issues described in Section 2.1.3 are currently postponed until a resolution is confirmed.

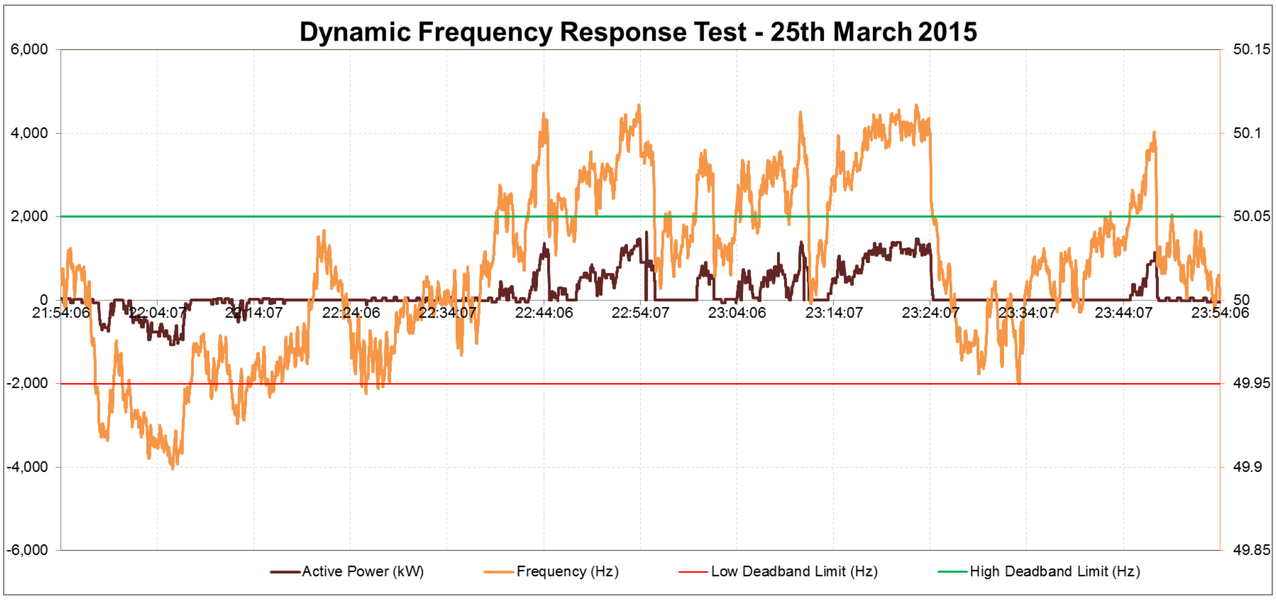

Figure 10: Dynamic Frequency Response Test using Active Power Dispatch from the ESS

A number of reserve tests were conducted to ensure that the ESS is reliable to deliver reserve services in the form of STOR to National Grid via the aggregator and SNS project partner KiWi Power. The reserve tests included:

- **Delivery mode testing in BESSM** – These tests ensured that the designed operating mode for the local control system adheres to the design specifications in delivering STOR (i.e. deliver instructed/contracted capacity within a pre-determined period of maximum 20 minutes and for 2 hours, or until a stop dispatch signal is received from KiWi Power's messaging system – KOMP).
- **Interface testing** – These tests ensured that the interface and messaging system between BESSM and KiWi Power's Dispatch Centre (via SNS messaging system-IBM Messaging through to KOMP) are functional and reliable in (i) delivering start-stop/dispatch signals from KOMP to BESSM and (ii) reporting in real-time the power utilisation and availability of the plant.

These reserve tests were completed and provided the required confidence to proceed with formal pre-qualification assessment with National Grid, which took place during 5-6 March 2015 to assess the reserve capability of the ESS.

The particular tests that were conducted for STOR pre-qualification assessment aimed to test the import and export capacity as well as the stability in power output and are described below:

- **Test 1** – STOR export capacity test: in this test the energy storage system was instructed to follow a STOR mode and in effect discharge (i.e. export energy) with 3MW for 2 hours, which is the minimum requirement from National Grid to participate in the STOR market. During the test (specifically between 4140 and 4280 seconds), frequency injections were simulated from BESSM software to test whether the storage system would be sensitive to frequency deviations during provisions of reserve.

- **Test 2** – STOR import capacity test: in this test the energy storage system was instructed to charge (i.e. import energy) with 3MW for 2 hours, to verify its capacity and recharging time. During the test (specifically between 4140 and 4280 seconds), frequency injections were simulated from BESSM software to test whether the storage system would be sensitive to frequency deviations during provisions of reserve.

Figure 11 show the results of both tests in terms of output power of the energy storage system as measured by National Grid's monitoring equipment.

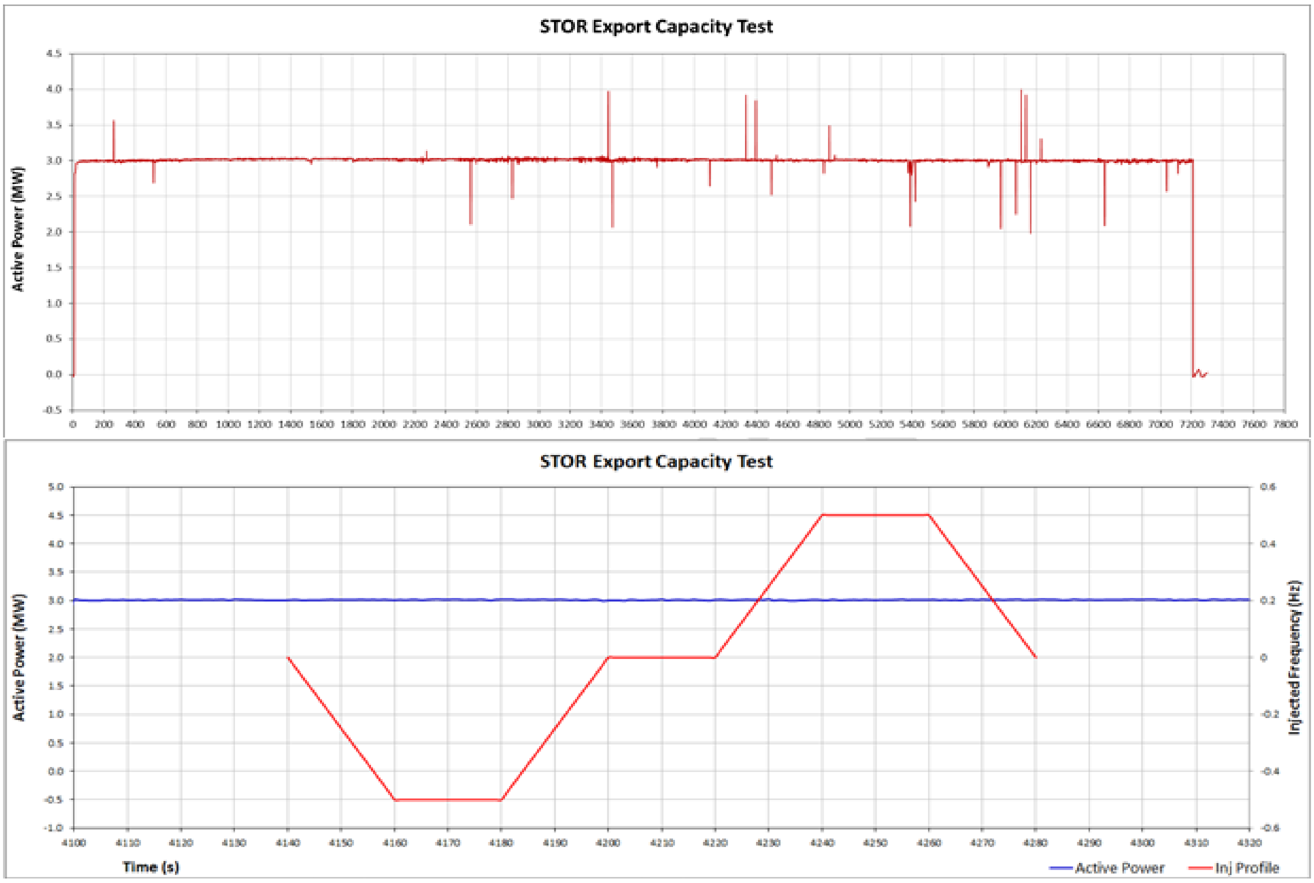

Figure 11: STOR Export Capacity Test Results

STOR import and export tests showed that while the ESS is in STOR delivery mode, the delivery is not affected by grid frequency. Despite the power toggling experienced, the performance in both import and export tests was deemed acceptable with less than 1% difference in energy delivered over the energy expected. It should be particularly noted that the performance measure in operational STOR delivery is the realised export energy over the expected export energy. Under-delivery is penalised when an agreed tolerance is exceeded while over-delivery is not penalised. In the particular export test realised for SNS, an over-delivery of 0.288% was achieved. The performance indicators for both import and export tests are shown in Table 2.

	Import	Export
Energy Expected (kWh)	6000	6000
Energy Realised (kWh)	5959.42	6017.25
Difference (kWh and %)	40.57kWh-0.7%	17.25kWh-0.3%
Within Delivery Tolerance (10%)	Yes	Yes

Table 2: Delivery Performance of STOR tests

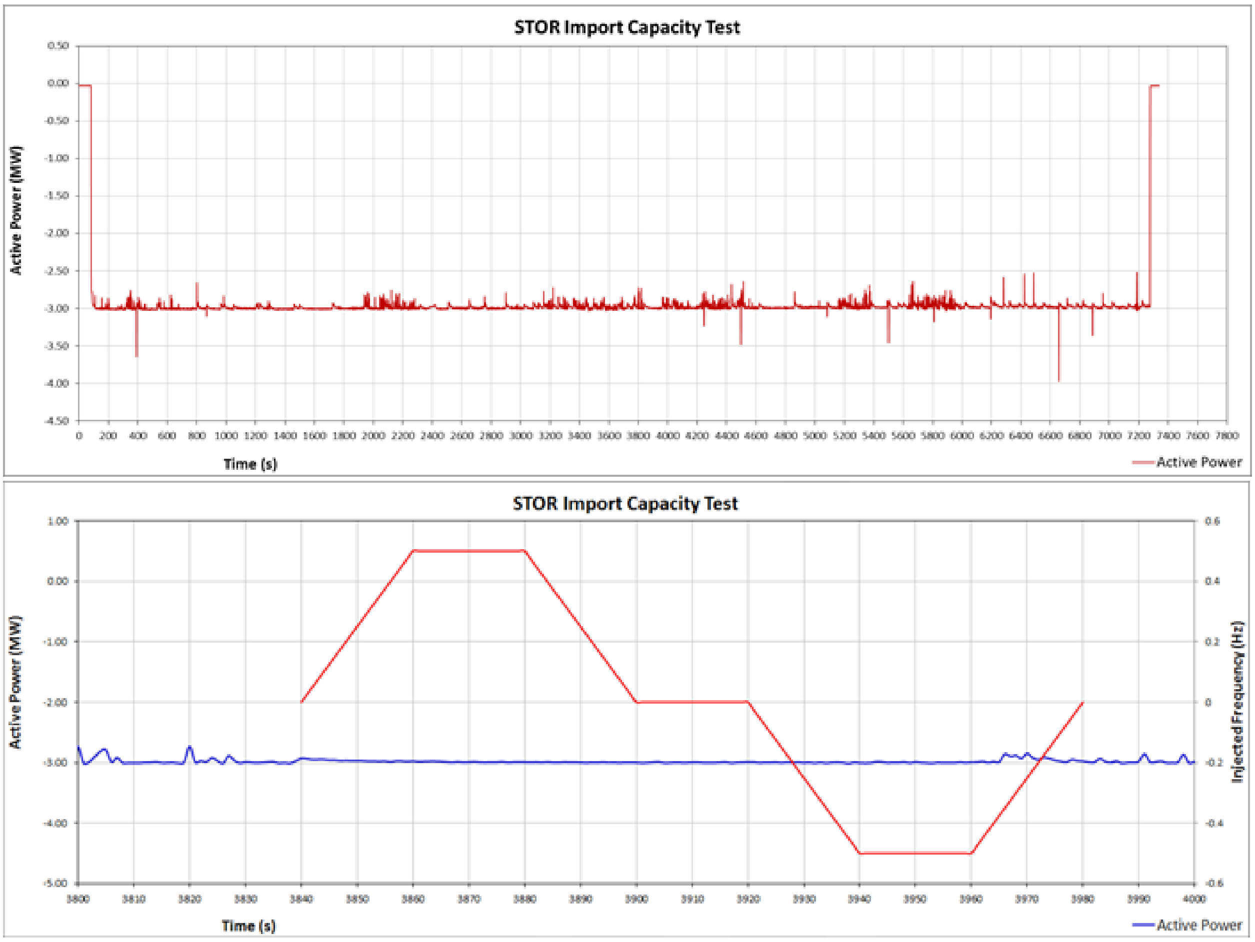

Figure 12: STOR Import Capacity Test Results

The pre-qualification assessment was therefore successful and the SNS system was successfully enrolled into KiWi Power's STOR programme. STOR season 1 (1-27 April 2015) was used to trial committed STOR. All STOR windows (with an exception of the morning window of 1 April 2015 that was reserved for resolving an unforeseen communication issue between BESSM-KOMP), were declared available with 3MW availability. No utilisation was required as the plant was not dispatched for providing STOR during that period.

2.1.5.3 Wholesale Market Trials

A number of triad warning notifications were received from the SNS Project partners Smartest Energy and KiWi Power during the triad period November 2014 to February 2015. Although the storage was reserved for investigations during the first two triad periods, it was successfully scheduled and dispatched to respond to the triad warning during the third triad period with a metered export of 1.598MWh. Figure 13 shows the active power of the storage system during the third triad period.

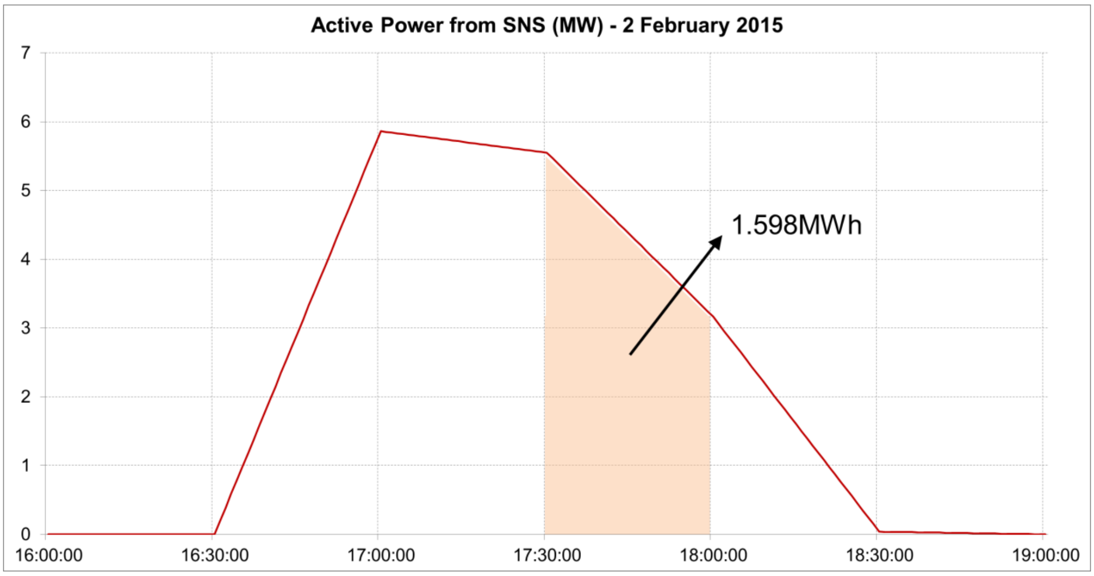

Figure 13: Active Power from SNS during the Third Triad Period

Table 3 below shows an overall summary of the trial performance during this reporting period.

Application/ Service	Availability/Requirements	Results
Peak Shaving	24 days with deviations over firm capacity experienced; Peak Power 3.2MVA; Peak Energy 5.41MVAh	Support provided. No N-1 outages requiring despatch.
FFR	Weekly potential for 6MW of Static or Dynamic Frequency response	N/A - Not yet trialled due to limitations on full capacity available
TRIAD	TRIAD periods announced: 1) 4 December 2014, 17:30 2) 19 January 2015, 17:30 3) 2 February 2015, 18:00	1 of 3 TRIADS covered: 1) Idle for investigations 2) Idle for investigations 3) Peak export of circa 1600kWh
STOR	April Committed Season: Weekday: 7:00 – 13.30; 19:00 – 22:00 Weekend: 10:00 – 13:30; 19:30 – 22:00	100% 3MW Availability for 222.5 hours (one single window unavailable due to investigations) 0 despatch calls

Table 3: Trial Performance of SNS from commissioning until end of April 2015

Key Issues Encountered

The instability of power output due to comms issues has led to the postponement of some DNO trials and hence the completion of the DNO service trial report has been rescheduled. Similarly, the restriction in stable power output has prevented the project from completing formal pre-qualification of Frequency Response at 6MW. However, it is currently being investigated whether the lower level of output currently available from SNS could still be pre-qualified, tested and accepted into the commercial service in light of the new 'bridging' arrangements published by National Grid which is intended to accept smaller storage and DSR units[5]. This would allow the project to continue commercial response service trials.

Due to the ongoing investigations for ensuring that full capacity (i.e. 6MW/10MWh) of the storage system is available, it has not been possible to complete all individual trials originally planned under each trial category. Hence the delivery of the full trial reports, as outlined in Section 8, has been re-scheduled for the following reporting period until the full capacity is enabled.

Nevertheless progress in several trial areas was made, as described in Sections 2.1.5 and actions have been taken to ensure that response and reserve trials can be continued with limited capacity (i.e. 3MW/5MWh) and deliver the learning required to prove the functionality of the ESS to provide tolling and frequency response.

Key Deliverables

- **SNS1.25 – Ancillary Services Testing Report** – A report from National Grid describing the STOR pre-qualification testing and passing the SNS facility for operation in the commercial STOR market
- A conference paper describing the functionality of the FOSS system was submitted and accepted for presentation in the Conference for Electricity Distribution (CIRED) 2015. The paper was prepared by the project partners of Newcastle University.
- An academic paper in which the sizing of the ESS was evaluated in terms of providing security of supply by minimizing the expected energy not supplied (EENS) was prepared by the partners from Newcastle University and submitted to the IEEE Journal on Sustainable Energy.

2.1.6 WS 4 – Commercial & Regulatory Frameworks

This work-stream is responsible for the commercial and regulatory aspects of the project, including assessment and validation of specific business models for storage, and identification of key regulatory barriers.

Smart Commercial Agreements

The key focus for this work-stream this year is the preparation for and delivery of the report entitled Evolution of Regulatory and Legal Arrangements for energy storage (SDRC 9.5, which is on track for delivery at the end of September 2015) together with understanding the commercial operating costs and service provision income due over the period.

During this reporting period a series of workshops have been held. These meetings gathered together relevant partners and UK Power Networks internal subject matter experts who reviewed and built on the legal and regulatory barriers work which was published in the Interim Report on the Regulatory and Legal Framework (SNS 4.13) last year. These meetings identified potential solutions to the issues and barriers published in the interim report.

The findings and potential solutions identified were presented to representatives from all DNOs and National Grid at the Electricity Storage Operators Forum meeting held on the 18 March 2015 in Leighton Buzzard. This meeting considered the various solutions identified with the aim of identifying a clear DNO preference. Whilst a common theme was identified, some attendees wished to consult more widely with colleagues within their own DNO. To help this process a summarised presentation of the issues and potential solutions was sent out to all attendees. Also offered, was the option for the WS4 lead to meet and present directly to any network company so interested. So far one bilateral meeting has been held, this was with Scottish Power on the 8 May 2015.

In addition to meeting and consulting with the other DNO's and the TSO, a number of storage developers and other parties including the Institute of Civil Engineers, have expressed interest in the work being done. In order to gather views from these parties, bilateral meetings have been held and the views and preferences expressed. Given the

[5] http://www2.nationalgrid.com/UK/Services/Balancing-services/Frequency-response/Firm-Frequency-Response/FFR-Bridging/#

extended interest, we are planning to hold a focus group meeting specifically for storage/renewables developers in the week commencing 6 July 2015.

Work has commenced on the drafting of the SDRC 9.5 report and the relevant views, concerns and conclusions of the consultation events held will be included. It is our intention to identify a clear set of proposed solutions to the issues and barriers identified. However, given the wide interest this may not be possible, and where not the arguments both for and against will be shared. Drafts of this document will be shared with the network companies in June before a final document is concluded in the summer.

Incorporated into the SDRC work is the investigation of issues, and barriers that energy storage integration into distribution network may face with respect to Distribution Use of System (DUoS) charges. A working paper has been developed and reviewed among the project partners and internal UK Power Networks subject matter experts. The working paper will be finalised and included in the SDRC 9.5.

The first energy statements have been received from Smartest Energy enabling invoices to be prepared and submitted by Smartest for the period November 2014 to April 2015. These cover all import charges, excluding DUoS which will be issued separately. Reciprocal invoices for export charges have been prepared by UK Power Networks and issued to Smartest Energy for the same period.

National Grid announced the triad periods for the last winter season. These were the 4 December 2014, at 17.30; 19 January 2015 at 17.30 and the 2 February 2015 at 18.00. As described in Section 2.1.5.3, as the SNS device was exporting 1,600kWh during final of the three settlement period, we expect to receive suitable recompense from Smartest Energy for this service which serves to reduce their peak demand during this period.

Key Issues Encountered

A minor issue was encountered with the HV metering of the storage facility which initially was reporting imported energy as export and vice-versa in the first commercial statements received. This was identified as an issue during commissioning of the transducer which had the terminal connections the wrong way around. The wiring was successfully swapped on 5 March 2015 and statements re-issued which resolved this issue.

Key Deliverables

No external deliverables have occurred during the reporting period.

2.1.7 WS 5 – Learning & Dissemination & Stakeholder Engagement

WS 5 was specifically created to ensure the effective identification, capture and dissemination of learning from the SNS project. Activities relating to the learning and dissemination carried out during this reporting period are provided in Section 7.2 of this report for clarity.

Key Issues Encountered

No significant issues have been encountered in this area.

2.2 Project outlook into the next reporting period

The next reporting period is critical in ensuring that the final defects and issues with the system are resolved to ensure that the operational trial phase can continue to make good progress. As highlighted earlier, this is now likely to involve some reasonably significant remedial work to the storage system before full capacity is available for all trials. However, the trial of a number of specific network and commercial services can still be progressed effectively. The focus of the next reporting period will therefore be across the following areas:

- Defect management and resolution of the storage system hardware and software issues;

- Completion of final testing phases including System Integration Testing of the FOSS platform;
- Day to day operation of the storage facility, following the established processes and refining them where appropriate;
- Ongoing execution of the trial schedule covering wholesale and ancillary service demonstrations, with capture, analysis and documentation of trial data; and
- Publishing the main regulatory and legal work, exploring potential solutions to the identified barriers for storage

Activities expected within the next reporting period relating to learning and dissemination are described in Section 7.3 of this report for clarity.

3 Business Case Update

One of the key purposes of the SNS project is to help quantify the general business case for the economic use of grid scale storage on the distribution network, when leveraged for additional benefits across the full electricity system. Work associated with developing this business case will come from the specific learning that is gained throughout the life of the SNS project.

This generic business case will be dependent upon the form of business model which is chosen and the assumptions that are made regarding all of the current unknowns. This project is looking to identify and quantify many of these unknowns and apply them to the various different business model structures to help drive forward the adoption of storage for the benefit of customers and industry. These business model structures were consulted upon in 2013 (SNS4.1 – Storage Business Model Structures Consultation)[6].

For the particular project installation, we are tracking changes to the main drivers of the business case and it is the project's intention to use this section to provide an ongoing update to the general economics of the installation as these drivers evolve and as further learning emerges.

During this period, the early operational experience has allowed the project to begin collecting real trial data relating to costs of operation, revenues and overheads in participating in certain services. This has included a favourable level of revenue from the trial of export during one of the triad windows, as described in Section 2.1.5.3. Revenues from triad have not been incorporated into the long term business case, as shown below, due to the challenges more generally in predicting and reliably securing benefit from such a service. This therefore serves to boost the potential future income stream benefit that may be achievable compared to the conservative estimates currently used, which only account for a contribution from FFR and STOR services.

At the time of writing however, the period of operation has still been too limited to reliably extrapolate to inform the longer term business case, but it is expected that sufficient trial learning will be available to further update the long term business case within the next reporting period. As such no material change to the expected long term business case has been made in this reporting period.

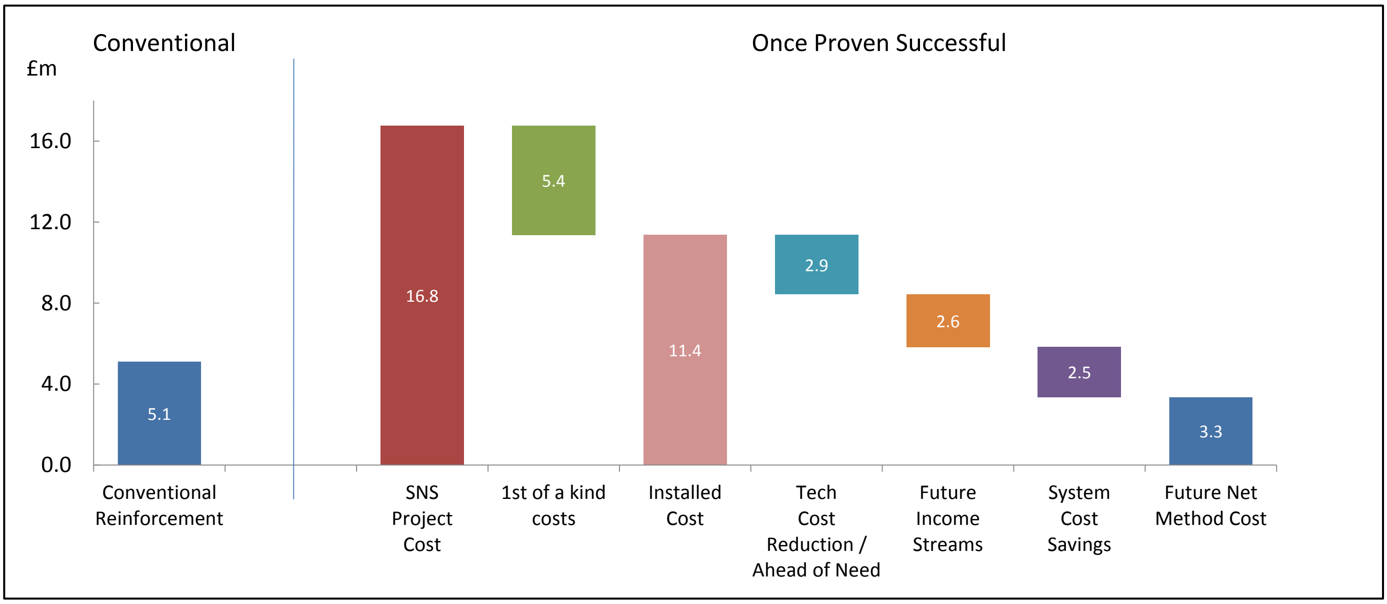

Figure 14: NPV Breakdown of Reinforcement Route incorporating SNS

[6] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Smarter-Network-Storage-(SNS)/Project-Documents/Smarter-Network-Storage-Business-model-consultation.pdf

By way of a reminder, the key assumptions relating to the discounted cash flow analysis are as follows:

- All values are Net Present Value, over a 10 year period;
- Discount factor used is 7.2%;
- 'Installed cost' represents the actuals from the site installation works, covering storage capex and opex including licence and maintenance fees currently contracted for and then extrapolated over the 10 year period, and estimated energy costs;
- 'First of a kind costs' represent non-core storage installation costs, including other R&D work, and first-of-a-kind development costs within SNS;
- 'Technology cost reduction' represents the expected price reduction in core storage technology occurring between the period of the SNS installation, and the point in time when storage would otherwise be installed as part of a BaU intervention to relieve the network constraint. This reduction was based on the 'Type-4' medium reduction trajectory used by WS3 of the Smart Grid Forum; however comparisons against current evidence suggests that cost reductions have already been more significant than this. Latest estimates for installed storage systems globally are shown in Figure 15 below from March 2015[7]; and
- System cost savings represents the wider system efficiencies materialising from reduced curtailment, reduced greenhouse gas emissions and system balancing and operation savings from displacement of peaking capacity. While no 'non-hydro' storage devices were awarded in the recent capacity market auctions, the auction price settled at £19.40/kW.

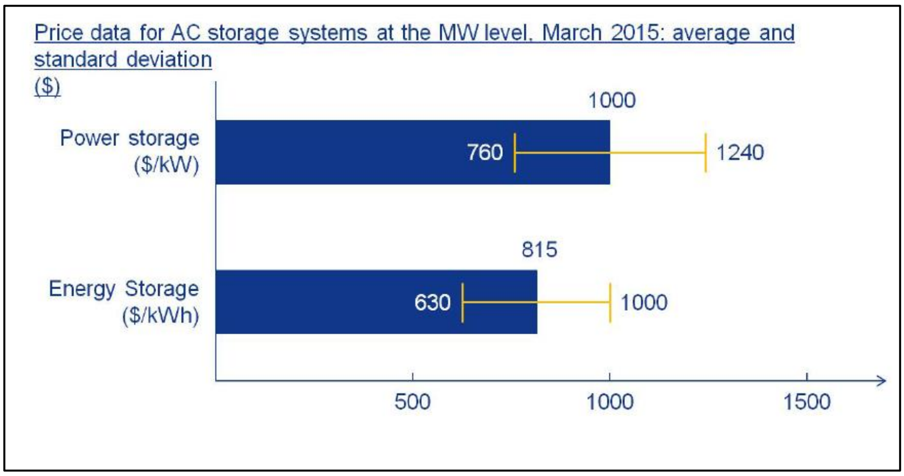

Figure 15: Storage System Installed Price Ranges ($)

4 Progress Against Budget

This section will be provided in Appendix A

5 Bank Account

This section will be provided in Appendix B

[7] http://www.cleanhorizon.com/blog/2015/03/

6 Successful Delivery Reward Criteria (SDRC)

SDRC	Criteria	Evidence	Progress	Date
9.1	**Design & Planning Considerations for large-scale energy storage.** Successful early capture and dissemination of learning related to the practical issues and consideration in the design and planning of large-scale distribution-connected storage by 1 October 2013.	• Minutes and notes captured from meetings with local planning authorities and environment agency. • Planning approval granted at either Leighton Buzzard Primary or an alternative contingency site. • The final design of the storage facility will be signed off by UK Power Networks Design Review Board. • A summary report of the key learning and considerations in securing planning at the trial site, and how this impacted designs, will be produced and shared through the project website.	This SDRC has been completed on schedule. The summary learning report is available on UK Power Networks innovation website.	1 October 2013
9.2	**Confirmation of the Smart Optimisation & Control System design.** Successful completion and sign off of the overall design of the Smart Optimisation & Control System by 30 December 2013. The functional design will be developed with operational partners and Durham University, and incorporate the description of business processes to be implemented across participants to facilitate the SNS Solution.	• Regular meetings held between UK Power Networks, operational partners, Durham University and AMT-SYBEX to further develop the full requirements and design, with minutes and notes captured. • The final design will be signed off by UK Power Networks, including approval by UK Power networks IT Design Authority Board. • A report describing the final design, optimisation and forecasting algorithms and business processes required will be produced and shared through the project website.	This SDRC has been completed on schedule. The technical report is available on UK Power Networks innovation website.	30 December 2013

Page 28 of 46

SDRC	Criteria	Evidence	Progress	Date
9.3	**Commercial arrangements for integrated use of flexibility.** The commercial arrangements for the independent service trials and optimised period of operation will be developed and translated into skeleton contract templates by 31 October 2014. These will provide the basis of commercial arrangements that could be tailored for other forms of flexibility and leveraged system wide by other DNOs. Practical and ongoing experience of the arrangements during the operational periods will be captured and reflected in the project final report (SDRC 9.8), with any recommended changes to these arrangements.	• Meetings will be held between UK Power Networks and the operational partners to discuss and design the necessary arrangements for the service trial demonstrations, with minutes and notes captured. • Completed commercial arrangements will be signed off by UK Power Networks legal counsel for the provision of reserve, response and wholesale market services using the storage. • Reviews of the commercial arrangements underpinning the service trials will be carried out by UK Power Networks and will be developed into contractual templates for reuse by DNOs and other industry participants and subsequently shared.	This SDRC has been completed on schedule. The learning report is available on UK Power Networks innovation website.	31 October 2014
9.4	**Energy Storage as an Asset.** Successfully commissioned energy storage device, with knowledge developed, captured and disseminated relating to the commissioning and operation. The knowledge generated through the early operational experience and training materials will be incorporated, along with methodologies for the asset management and maintenance of storage. A visit to the storage facility will be organised and hosted for interested DNOs and other stakeholders to provide an additional opportunity for dissemination.	• Sign off of documentation of the installation, commissioning and test of energy storage device. • Training will be undertaken with operational field staff relating to safety and operational procedures of the energy storage device and training materials will be shared. • Meetings will be held with asset management to establish and design appropriate asset management methodologies for storage. Minutes and notes will be captured and the methodologies and considerations for large-scale storage will be shared. • At least one visit to the storage facility for DNOs and other stakeholders will be organised and hosted by UK Power Networks.	This SDRC has been completed on schedule during this reporting period. The learning report is available on UK Power Networks innovation website. The completed unit has required some remedial works and aspects associated with the interaction between the AC-DC / DC-AC converters and the batteries themselves which are being investigated. UK Power Networks has agreed with National Grid to postpone pre-qualification tests for Fast Frequency Response (FFR) until both parties can be certain of reliability.	29 May 2015

Page 29 of 46

SDRC	Criteria	Evidence	Progress	Date
9.5	**Evolution of Regulatory and Legal Arrangements for energy storage.** This criterion relates to the assessment of regulatory, market and legal considerations in the wider deployment of distribution-connected storage and development of recommendations to facilitate the optimum use of storage and other forms of flexibility. This assessment, incorporating learning captured during the development and operation of trials will be completed by 30 September 2015.	• Regular meetings will be held with project partners and other stakeholders to discuss ongoing reviews and amendments to the regulatory frameworks and the impact on energy storage, incorporating EMR, Electricity Balancing SCR and other on-going developments. Minutes and notes will be captured and stored. • Interim reports and or briefing notes may be published to facilitate these meetings. • Assuming that the issues identified have not been solved in regulation in the interim period, issue a report detailing the market and regulatory issues affecting storage, the way future developments may impact storage flexibility and possible changes required to regulatory and commercial frameworks will be produced and shared through the project website.	A series of workshops have been held to review the legal and regulatory barriers identified in an interim report published last year. Potential solutions have been identified and these have been presented to suitable representatives from all DNO's and the TSO. Further consultation is ongoing. Drafting work of the report has begun.	30 September 2015
9.6	**Analysis of integrated energy storage contribution to security of supply.** This criterion relates to the studies undertaken on the contribution of energy storage to security of supply over various time scales. An emphasis will be placed on quantifying the risks to supply when the network is supported by energy storage with a limited amount of energy, taking also into account that storage may be used to provide other services.	• Scenario tests will be designed to demonstrate and assess the storage contribution to network security by Imperial University. • Operational data and performance relating to the trials will be captured and analysed. • Assuming that storage has not been incorporated into the security of supply standards within the Distribution Code in the interim period, a summary report will be produced by Imperial College London describing the methodology applied, key assumptions and results of the analysis of the benefits of energy storage to distribution networks and contribution to security of supply, including recommendations for amendments to network design standards.	Activities contributing towards this SDRC include: • The development of trial designs that will deliver the operational learning required to assess contribution to security of supply. • Meetings/conference calls have been held with Imperial College London to scope, monitor and track progress. • Development of requirements for ancillary services testing and delivery with National Grid, KiwiPower, S&C Electric and Younicos. This SDRC remains on schedule to be delivered as planned.	29 January 2016

Page 30 of 46

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SDRC	Criteria	Evidence	Progress	Date
9.7	**Successful demonstrations of storage value streams.** The end to end learning from the planning to the operational performance in performing a range of services with the storage facility will be captured and shared. Both technical data, relating to the impact of the use of the storage on the distribution network, and commercial data, relating to the way in which the service was provided and any economic return for the service will be identified and shared.	• The detailed trial plans for each storage service, including key requirements and processes required, will be captured through meetings with UK Power Networks and operational partners and shared through the project website. • The operational data relating to the impact on the distribution network will be collected and stored by Durham University. Any financial performance data will be captured and reported by UK Power Networks. • A report assessing the capabilities of the storage device in providing the range of services will be produced and shared, incorporating an assessment of the relative value of services provided.	Activities contributing towards this SDRC include: • The implementation and execution of commercial arrangements underpinning value streams and the management of invoicing and reconciliation processes between UK Power Networks and the energy supplier and the aggregator. • Initiation of the service trials and ongoing operation of the storage system. This SDRC remains on schedule to be delivered as planned.	30 March 2016
9.8	**Full Evaluation of the SNS Solution.** A detailed final project report describing the project findings, knowledge generated and recommendations on the wider roll out of the SNS Solution will be produced. The report will be designed to provide sufficient information to: • Validate and assess which future business models for storage are viable • Inform stakeholders on the commercial arrangements and software platforms necessary to enable these business models. • Inform the ways in which storage can be most economically incorporated into future DNO business plans. • Assessment of the impact on different future market scenarios on the business cases, including varying carbon prices, high versus low wind penetration and demand side response. • Compare the performance and value of storage flexibility to other forms of flexibility • Inform the design and structure of future product or services that storage may provide to DNOs and TSOs.	• Lessons learned throughout the project have been captured and recorded and shared. • Analysis has been carried out on the business models for storage, and validated with commercial results from operational trials. • Comprehensive end of project report developed, incorporating the information above, and shared through the project website and other dissemination channels.	Activities contributing towards this SDRC include: • Completion of the business models consultation and collation of responses • Completion of the construction, installation and commissioning of the storage • Initiation and ongoing operation of network and commercial service trials • Ongoing assessment and capture of the lessons learned This SDRC remains on schedule to be delivered as planned.	30 December 2016

Page 31 of 46

7 Learning outcomes

7.1 Main Learning Outcomes from the Reporting Period

During this reporting period, SNS has continued to capture specialised learning relating to the construction, installation and commissioning as well as the regulatory and market aspects of distribution-scale energy storage. The key learning outcomes from this reporting period are explained below.

A number of key findings have been identified through the ongoing defect management and early operation of the storage facility. These include:

1. **The provision of triad avoidance service is likely to form an important part of the portfolio of services for a commercial operator, which in some scenarios could cause conflicts with services to a DNO**

   Trial operation in this reporting period has involved the SNS facility operating to perform a triad avoidance service for the energy supplier, providing export during the window of 2 February 2015.

   The expected benefit from this service is not factored into the long term business case for SNS, due to the challenges in providing this service, which can be hard to predict and secure. In addition, the periods of expected availability for this service, when system demand is at its peak, directly coincide with the broad periods when network support is likely to be required at the SNS trial site. Analysis has shown that the coincidence of the local network demand peak is not necessarily coincident with the system peak, and therefore there could potentially be conflicts in the timing of energy requirements for both these services.

   The level of revenues available from this service are on a comparable basis with the provision of other commercial services, such as STOR and FFR and hence could lead to commercial conflicts of interest for operators involved in both wholesale market services and network services. Under the DNO Contracted model the direct control of network support can be prioritised as needed by the DNO over the purely commercial triad service which negates this as an issue. However, under the Contracted Services (third-party owned/operated) model, there may be a strong incentive to favour the provision of the triad service over any network support obligations. This conflict may lead to onerous penalty terms in contracts, or an inflation of the value that has to be paid for network support to secure it; both of which could lower the viability of business case for DNO and/or third party.

2. **EMC compatibility testing and Factory Acceptance Testing should be thoroughly carried out using representative layouts, connections and scales of equipment as close as possible to the 'as-installed' system**

   The additional investigations carried out during this reporting period in response to the storage stability issues have identified a level of electromagnetic emissions that have caused issues with communications protocols and power supplies amongst sub-systems of the installation.

   Although it is typically impractical from a cost perspective to bring together all system components at a scale to test 'as installed' before being taken to site, (in particular for installations of this scale), it is clear that at a minimum cable connections as per the final installation should be specified to be used at the Factory Acceptance Testing stage. It is also clear that additional or improved standards (or at least guidance on the special case parameters for existing standards) are required to ensure that equipment for use in energy storage systems is sufficiently tested off-site. There is work ongoing in IEC TC120, specifically working group two with the scope: "To define Unit parameters and Testing methods to assure the system capability and performance of Electrical Energy Storage Systems (EESS)" although it is uncertain whether this would address the specific issues identified here.

   As many of these issues arise from system integration there may also to be benefits from standards or guidance defining a voluntary specification for the interfaces between ESD components, including limits on conducted and radiated emissions. This might include information to be shared for modelling or assessment purposes such as switching frequencies and system electrical properties, e.g.: capacitance/inductance.

3. **Earthing systems appropriate for high frequency currents should be specified for future installations of building-housed storage to avoid unwanted circulating currents**

During commissioning tests, current flow was discovered at approximately 35kHz, a harmonic of the switching frequency of the power inverters and choppers, particularly when both halves of a PCS were in operation. What was not anticipated was that at this frequency skin effects led to a number of points that were both solidly earthed together having touch potentials of 45V to 50V. This high frequency current was also inducing circulating currents in the surface of the metal tray-work supporting the earth cables causing an increase in temperature in the metal and raising the risk of safety issues.

The problem was identified to arise from the fact the building earth system was designed for a 50Hz AC system and agreed with S&C Electric, who designed the connections from their equipment to the building earth system. As a mitigation, an additional earth conductor was designed and installed during February 2015 between the equipment and the building earth system and additional building earths were installed to provide as short as possible a route for the current flow to ground. It is unlikely that this issue would have occurred had the equipment installation been at ground level as the earth conductor installation would have been significantly different.

4. **Consideration needs to be given to appropriate validation test methods for frequency response behaviour**

From the pre-qualification testing carried out in collaboration with National Grid during this reporting period, it was evident that there were shortcomings in translating the existing tests and approach for ‘traditional’ spinning forms of generation to storage systems. The standard test approach that National Grid expected to use involved the injection of an analogue frequency signal to force a response from the storage plant. While this is appropriate for spinning generation, the SNS storage system had no analogue ‘input’ into the frequency control loop as a result of the software-driven nature and digital SCADA system that provides this control behaviour.

The SNS system measures and utilises frequency solely on the digital control system (BESSM) side, and translates this to appropriate set points to drive the storage output according to the active control mode. As a result there initially was no possible way for the digitally created input frequency profile to be measured at the ‘output’ of the physical network connection point by a monitoring transducer, meaning National Grid could not record or validate the time lag between frequency change and output response. As a result additional test equipment and approaches had to be developed and tested.

5. **Control systems that have no synchronisation in the architecture at the system level may cause small fluctuations in power output, if they choose to optimise power delivery amongst inverters**

In order to manage and optimise state of charge amongst batteries, the BESSM control system continually assesses the optimum combination of BESDMs (which are individually associated with a single inverter) to use to provide the requested level of power export (or import). It will use a smaller number of BESDMs at any time operating at a higher power output as this reduces switching losses, and switch or handover between different BESDMs to ensure the state of charge remains balanced. During the handover between individual BESDMs units, there are occasionally short delays in the fast ramping up and ramping down of power from these units, due to the cycle time of each system (BESDM and SMS) and the communications link between them.

Depending on the timing of these ramps, these very short delays can lead to a situation where the first unit ramps down before the second has ramped up, or where the second unit has ramped up before the first has fully ramped down. This causes some minor and short-term (~1MW for ~1sec) fluctuations in overall power delivery at the point of common coupling, and is most clearly illustrated in Figure 11. Assessment has deemed it not possible to eliminate these fluctuations altogether as there is no synchronisation in the system architecture at the SMS level in this installation. Due to their low magnitude and short duration, these fluctuations are not deemed to have a significant impact on the distribution network, nor were they counted by the system operator National Grid as evidence of non-delivery.

6. **Relatively simple parts of the overall solution can become single points of failure that could have a significant effect on network support operations or commercial services. Redundancy and resilience should be considered at all sub-system and IT levels**

   During the first trials of the STOR service, the project experienced an issue with the IBM messaging system, which caused the storage to be completely unavailable for the first morning window of the Committed STOR season during April. The issue was identified as being caused by a 'full' message queue on one of the other queues to the FOSS system, which had caused the IBM messaging broker to stop routing messages correctly. At this stage the trials were still using the test environment for the messaging system, and hence it is expected not to be an issue once fully deployed to a production environment and all queues are being processed correctly. However it highlighted that despite redundancy built in at many major levels (inverter, battery, control system server, power supply and network connection level); relatively simple parts of the overall communications solution had the potential to have a disproportionate effect on system availability and reliability if redundancy and resilience were not considered.

7.2 Learning, Communications and Dissemination Activities in this Period

As described previously, a comprehensive Knowledge Dissemination Roadmap has been developed in order to capture all the key learning activities and events. This has continued to evolve and be updated with the project and is available on request.

There are four core elements to the Knowledge and Dissemination Roadmap, covering the following areas:

- Internal Communications;
- External Communications;
- Local Engagement; and
- Knowledge Dissemination.

The following provides an update on the progress on each of the above elements:

7.2.1 Update on Internal Communications

- **Control Engineer training** – A number of training sessions have been carried out with our control engineers to introduce them to the SNS technology, control diagram information and principles of operation (March 2015);
- **Article in 'Cable'** – An article about the project was featured in 'Cable', the internal company magazine which is distributed to all field employees across the company;
- **Live Linesman Conference** – A presentation and exhibition stand on SNS and the wider Future Networks portfolio at the conference for UK Power Networks Linesman (March 2015);
- **Asset Management briefings** – Meetings have been carried out with members of the Asset Management directorate in order to develop the approach for incorporating the storage into business-as-usual asset management systems and processes.

7.2.2 Update on External Communications, Knowledge Dissemination and Local Engagement

- **Battery forum Deutschland** – The project was presented by battery management system provider, Younicos, at a battery conference in Germany (January 2015);
- **ESOF Good Practice Guide Launch Event** – The project's commercial and regulatory work was presented as part of the ESOF launch event for the Good Practice Guide (Jan 2015);

- **Electricity Storage network Annual Symposium** – The regulatory and legal learning from the project was presented at the annual event of the Electricity Storage Network (Jan 2015)**;**
- **Smart Energy UK & Europe 2015** – The project and detail of the latest commercial business case work was presented in London (January 2015);
- **Florida Power & Light, Energy Storage Summit** – An overview and details of the construction and installation, and business case work was presented as part of a knowledge exchange event with a US-utility in Florida (March 2015);
- **REA Energy Storage Event** – An overview of the work of the Energy Storage Operators Forum group was provided, and an overview of the SNS project at the first meeting on storage of the Renewables Energy Association (March 2015);
- **ESOF Meeting & SNS Tour & Dissemination Event, hosted at Leighton Buzzard** – The ESOF meeting was hosted onsite in Leighton Buzzard, and combined with a technical tour of the energy storage facility for the other network operators. A session was also held to consult on the latest regulatory and legal work underway to gauge views on appropriate solutions for the regulatory barriers for licensed operators.

Figure 16: Other network operators on a technical tour of the SNS facility during the ESOF Meeting

- **Commercialisation of Energy Storage in Europe; McKinsey and FCH JU** – Contributions from the SNS project have been provided and referenced in this report, supported by the European Commission, analysing the development of the European electric power system towards 2030 and the role and commercial viability of energy storage;
- **Scottish Renewables Annual Conference (by SmartestEnergy)** – A presentation by project partners, SmartestEnergy, introducing the project and the learning so far (March 2015);
- **BBC Radio 4 Today Programme** – The SNS project was featured on the Today Programme in a piece about solar energy and energy storage by Roger Harrabin (March 2015);
- **Carbon Trust TINA refresh and project Knowledge Exchange** – An interview was held by the Carbon Trust with the SNS Project Lead, which provided an opportunity to disseminate learning to guide a refresh of the Technology Innovation Needs Assessments (TINA), and also experiences & progress were shared on the regulatory and commercial aspects to inform the development of a Carbon Trust project looking into commercial models and regulation for storage (March 2015);
- **Parliamentary Briefing POST note on Energy Storage** – The SNS project contributed heavily to the development of a new parliamentary briefing note on energy storage, covering the role of storage in the energy sector and current barriers and policies[8]. The POST note will be circulated to House of Lords and House of Commons members and will inform the new post-election Government of key issues relating to storage (March – April 2015);

[8] http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/publications/

- **Utility Week Live 2015, Birmingham** – The SNS project, and the latest learning was presented in a session entitled 'Storage supporting the distribution network' (April 2015);
- **Large Scale Solar UK Conference, Bristol** – The SNS project, and the latest learning was presented at the Large Scale Solar conference, attended by the renewable development community (April 2015);
- **Newcastle University Academic Paper – Probabilistic Sizing of Electrical Energy Storage for Demand Peak Shaving with Static and Real-Time Thermal Ratings; D.Greenwood, P.Taylor, N.S.Wade** – the SNS project data and learning has fed into an academic paper, to be published by Newcastle University (April 2015)
- **SNS Tour and Dissemination Event for Citi University Postgraduate Students** – An opportunity was provided for 11 post-graduate students in power systems to visit and tour the SNS facility and learn about the project (April 2015);
- **SNS Tour and Dissemination Event for Belectric & National Grid** – An opportunity was provided for National Grid and Belectric to visit and tour the SNS facility as part of the NIC funded 'SMART Frequency Control' project to help contribute to their work around battery storage assets (April 2015);
- **ETI Strategy Group (SAG)** – A detailed presentation on both the construction and commercial aspects of the project was made to this group, formed from (energy) strategy experts from the wider energy industry and large industrial companies (April 2015);
- **Energy Storage Word Forum 2015** – Due to specific interest and for the third successive year, the project presented an update on SNS to this prestigious audience of world storage professions. This year the conference was held in Rome (April 2015);
- **DG Energy, EU Commission, High level roundtable discussion** – The project was invited to participate in a roundtable discussion with the Director General of Energy for the European Commission. The topic was the "Strategic contribution of energy storage to energy security and internal energy market", involving presentations from Dominique Ristori and Paul Rubig, MEP;
- **Institution of Civil Engineers (ICE)** – A presentation/meeting was held to inform the ICE of the learning gained to date. In particular, discussions around the commercial and regulatory framework issues were held in order to help inform the ICE in formulating their proposed policy on storage. (May 2015);
- **IET Storage Event – "What's next for the grid?", London** – The SNS project has contributed to the development of this IET event on storage, and will be presenting findings from the project (June 2015);
- **CIRED Conference Paper: Scheduling power and energy resources in the Smarter Network Storage project, Newcastle University** – the SNS project and the optimisation and forecasting techniques have been accepted as a paper at the 2015 CIRED conference (June 2015);
- **CIRED Conference - Roundtable Participation** – The SNS project will be discussed and presented at a roundtable session entitled "Energy Storage to alleviate distribution network constraints" at the 2015 CIRED conference (June 2015).

7.3 Learning and dissemination activities over the next reporting period

In the current reporting period, there has been significant interest in the facility both across the UK and internationally which is expected to continue into the next reporting period. A number of visits for stakeholders have already been carried out, and two dissemination events where tours of the SNS facility and an introduction to the project are planned to be carried out in the next reporting period for both external stakeholders, and internal colleagues, with the aim to share the learning and encourage the replication of energy storage projects.

The project will also continue to disseminate internally, through ongoing training and briefings to ensure local network and Control staff are confident in the use of the facility.

Confirmed activities are summarised below:

- External SNS Tour and project Dissemination Event (July 2015);
- External SNS Tour and project Dissemination Event (October 2015);
- Internal SNS Tour and project Dissemination Event (July 2015);
- Internal SNS Tour and project Dissemination Event (October 2015); and
- Presentation at Infrastructure Asset Management Conference, London (September 2015).

8 Intellectual Property Rights (IPR)

During the current period, the following key IP has been generated:

WS	Id	Product	Owner
WS 1	SNS1.10	Inspection and Maintenance Procedures for Storage	UK Power Networks
WS 1	SNS1.11	SDRC 9.4 – Energy Storage as an Asset Learning Report	UK Power Networks
WS 1	SNS1.12	SDRC 9.4 – Energy Storage as an Asset Evidence Report	UK Power Networks
WS 2	SNS0.4	Overall Solution Acceptance Report	UK Power Networks
WS 2	SNS2.10	SOCS Training	UK Power Networks

The following IP is expected to be generated during the next reporting period:

WS	Id	Product	Owner
WS 3	SNS3.6	DNO Service Trial Report	UK Power Networks
WS 3	SNS3.7	Reserve Trial Report	UK Power Networks
WS 3	SNS3.8	Response Trial Report	UK Power Networks
WS 3	SNS3.9	Wholesale Trial Report	UK Power Networks
WS 4	SNS4.7	SDRC 9.5 Evolution of Regulatory and Legal Arrangements for energy storage	UK Power Networks
WS 4	SNS4.9	SDRC 9.5 Evidence Report	UK Power Networks

9 Risk Management

The SNS project has established a rigorous and proactive risk management process, as described in the SNS Project Handbook. It allows for the communication and escalation of key risks and issues within the project, it also defines where decisions will be made and how this will be communicated back to the workstream level where the risk or issue has arisen. Risks are reviewed fortnightly at project level by the Project Board. Key project risks are then escalated to the Project Steering Committee for review and approval of the mitigation on a monthly basis.

9.1 Full Submission (BID Risks) – update

This section is provided in Appendix C.

9.2 Risks raised in the current reporting period

Ref No.	RAG Status	WS	Risk & Impact Description	Mitigating Actions
R0115	G	WS 3	Metering records from Smartest energy do not align with records from Siemens or data recorded in PI. Inaccurate billing from Smartest and inaccurate internal reporting and reconciliation within the SNS project.	Data between Smartest and Siemens have been validated and we are currently awaiting for first invoice and web access
R0116	Closed	WS 1	Issues with harmonic currents and ongoing instability mean that the storage device is not fully operational in time to meet SDRC9.4.	**Risk closed:** SDRC 9.4 report completed on time
R0117	Closed	WS 1	Delivery of manuals and as-built drawings not received in time to prepare for SDRC9.4.	**Risk closed:** SDRC 9.4 report completed on time
R0118	G	WS 1	Battery cell failure may indicate wider problem with Samsung installation. Significant replacements might be required.	Follow up investigation under way, following the failure as described in Section 2.1.3.3.
R0119	A	WS 2	Limited handover of testing activities from Testing Lead to WS2 and WS3 lead causes testing activities to lag behind, and defects to be poorly managed through to conclusion.	Ensure the team are willing and have the tools/knowledge to pick up additional responsibilities for completing the testing strategy, and ensuring defects are properly logged, tested and managed through to resolution.
R0121	A	WS 2	The SCADA team are looking at changing the tag names of all the EPN PI tags as part of the EPN ENMAC upgrade to V5; meaning that the FOSS system will need to be updated to read the new PI Tag name(s). The risk is that the change is not well planned or coordinated.	Ensure close coordination with Peter Brien to understand when the changes will take place, and what the new names will be.

Ref No.	RAG Status	WS	Risk & Impact Description	Mitigating Actions
R0122	G	WS 1	Although the battery earth fault protection has been tested and functions correctly it is possible that an earth fault in a battery in the middle of a string with have a voltage very similar to earth which will result in the earth fault not being detected. This may cause a problem for a second earth fault or other contact with that battery string.	Monitor for subsequent earth faults to assess probability – it is unlikely this will occur and not be detected.
R0123	G	WS3	The control system feedback loop introduces some latency in the system response which may make the system unsuitable for future potential services that require extremely fast response.	Re-assess risk & monitor following repeat of qualification testing for FFR. Evaluate in light of any new market services that are developed in the future.
R0124	A	WS3	The remedial works necessary, as proposed by S&C to resolve resonating voltage issues, to ensure stable operation of 6MW, mean that the storage system may not have sufficient time to perform all trials to meet SDRC 9.7 (Demonstration of all Value Streams)	Investigations with Partners into whether approval can be given for FFR and Tolling to be performed commercially with 3MW capacity.

10 Consistency with Full Submission

The SNS project is on track to deliver the learning consistent with the full submission.

The following details are noted to have changed since full submission:

- S&C Electric Europe replaced A123 Systems as the supplier of the storage system in early 2013;
- Newcastle University is now carrying out the scope of work originally to be undertaken by Durham University, representing a change of organisation as Project Partner, but no change to the cost, scope or quality of work to be delivered. This change request was approved on 4 July 2013; and
- The future expandability of the SNS facility is currently restricted to approximately 18MWh, based on currently available storage cell technologies. This is down from 24MWh as originally envisaged as a result of a change in battery-cell supplier which requires the use of a lower DC busbar voltage

11 Accuracy Assurance Statement

We hereby confirm that this report represents a true, complete and accurate statement on the progress of the Smarter Network Storage Project in the six-month period from January 2015 – June 2015 and an accurate view of our understanding of the activities for the next reporting period.

Signed ....

Date 18/6/15 ....

Suleman Alli
Director of Strategy and Regulation
UK Power Networks

12 List of Appendices

Appendix A: Progress against budget (CONFIDENTIAL)

(See separate document)

Appendix B: Bank account (CONFIDENTIAL)

(See separate document)

Appendix C: Bid Risks Update

Ref No.	RAG Status	Risk & Impact Description	Mitigating Actions	Update
R0005	G	The installed storage technology fails and needs to be disconnected from the network whilst being repaired or replaced.	Close collaboration with the storage device manufacture to ensure the design meets UK Power Networks specification and standards through robust testing (maintenance & training delivered by the storage device manufacture). Replacement parts are to be made easily available. With a regular maintenance cycle.	Design approved at Design Review to attempt to mitigate risk. Engineering Operating Standard created to specify safe maintenance and operation required through lifetime.
R0007	G	The installed storage technology has a catastrophic failure, which adversely affects customers' supplies and needs to be disconnected from the network resulting in project delays.	Close collaboration with storage device manufacture to ensure the design meets UK Power Networks specification and standards through robust testing (maintenance & training delivered by storage device manufacture). Carry out a full set of test to minimise the possibility failure and affect upon customers.	SWIFT assessment carried out to highlight areas needing particular focus during design process. Fire testing completed and demonstrated thermal runaway does not occur. Engineering Operating Standard created to specify safe maintenance and operation required through lifetime.
R0012	G	The storage device manufacture goes out of business after the storage device has been paid for and delivered; resulting in lack of continuity and covers should the unit fail.	Carry out full financial diligence checks in line with approved standards of practice and the UK Power Networks procurement procedure(s). Arrange a software ESCROW and novation of liabilities to OEMS.	Parent guarantees included in contract.
R0013	G	A storage battery fails with severe consequences after the UK Power Networks device has been commissioned, resulting in limited confidence in the device, so it is disconnected until all test have been completed.	A full set of quality tests to be completed before installation, with the design and operation meeting the UK Power Networks requirements. Ensuring full confidence in the equipment installed. Monitor defects and issue reports supplied by storage device manufacture for existing installs.	Performance bond and design indemnity included in contract. Fire testing completed and demonstrated thermal runaway is not likely.

Ref No.	RAG Status	Risk & Impact Description	Mitigating Actions	Update
R0014	G	The installed storage technology causes damages to UK Power Networks asset(s), so needs to be disconnected from the network whilst issues are resolved causing delays to the project.	Carry out a full set of tests to minimise the possibility of failure. Close collaboration with storage device manufacture to ensure the design meets UK Power Networks specification and standards through robust testing (maintenance & training delivered by storage device manufacture). Replacement parts are to be made easily available. With a regular maintenance cycle.	Investigations on the system have identified the root cause of circulating currents and heating effects. Additional earthing installed has mitigated this issue.
R0015	Closed	Equipment is stolen or vandalised whilst on site, but not commissioned.	MUS providing temporary CCTV cameras to monitor site; manned presence not required at this stage.	Risk closed: equipment is now commissioned
R0016	G	Equipment is stolen or vandalised after commissioning, requires repairs, so reduces the time to realise benefits.	Improve security at the site with a manned presence.	Permanent, monitored CCTV system now installed and monitored by Security Management Centre,
R0018	A	The storage device does not perform to specification, so not all benefits are realised. The limited capacity of the installation increases the risk that progress on commercial services trials may be delayed, and revenues generated are reduced.	Regular design meetings/reports. Key stakeholder engagement to ensure specification can comply with UK Power Networks design policies and procedures. Investigations into the possibility of carrying out commercial FFR and tolling with 3MW capacity.	Performance KPIs included in contract. Further investigations have been carried out by S&C electric this reporting period, which have identified resonant voltage issues between the two halves of a PCS unit. Mitigating solutions are under assessment, but are likely to require some electrical rework of the installation.
R0020	A	Site load growth exceeds expectations, pushing peak demands beyond the spare capacity range of the battery.	Detailed load studies to understand maximum demand and future increases. Estimates of availability to be refreshed on a regular basis. Ensure ongoing tracking of demand.	Additional storage provision has been included within the design to allow for capacity to be increased to 18MWh. Future connection requests continue to be monitored. Evaluation of load profile to be reviewed on ongoing basis.

Ref No.	RAG Status	Risk & Impact Description	Mitigating Actions	Update
R0026	G	The lack of available technical, commercial and project resources result in delays in project delivery.	Resourcing plan completed during resources within UK Power Networks/Future Networks.	Project team mobilised, including appointment of two external contractors to ensure deliverables remain on track. Ongoing resourcing meetings being held to ensure regular reviews and monitoring of resource.
R0027	A	Significant connections activity in the area puts pressure on SNS business case.	A connections customer prepared to invest a lot, could pay for the third circuit and transformer ahead of expected date. Or there could be pressure on SNS to release the capacity for connectees.	Monitor and track connections activity and materialisation of load growth Develop action plan for post-security of supply operation (e.g. as part of ANM).
R0029	G	Unfavourable changes in legislation or market arrangements that restricts on the usage and reduces the identified benefits.	The project has been scoped to look at multiple ownership/operational structures, so should be robust to legislative changes.	The project has been scoped to look at multiple ownership/operational structures, so should be robust to legislative changes. Trial demonstrations still possible in conjunction with National Grid on a demonstration basis only.
R0038	A	During the project delivery stage the appropriate UK Power Networks staff do not engage adequately or in a timely manner with the Project. Resulting in poor engagement and delays.	Design and implement a robust internal and external stakeholder road map to identify all the key stakeholders. Step up engagement with control team and Operational teams as we approach commissioning.	Efforts to integrate with Network control system and SCADA continue to be intensive. Ongoing internal communication activities and training to be continued in next project phase.
R0042	G	Key Project partner(s) withdraw their participation in the SNS project during the project has started, leading to delays.	Tender process was carried out for several projects aspects and provides alternatives therefore reduces this risk.	Partner forums continue to be held to ensure good engagement in project work.

Ref No.	RAG Status	Risk & Impact Description	Mitigating Actions	Update
R0043	G	Partner resources not available to complete work, attend meeting etc. Resulting in project delays and issue with quality of work.	All partners are to provide multiple names as contacts, with deputies of the same standing. Also partners are to provide an escalation path should any issues be identified.	All partners have provided multiple names as contacts, with deputies of the same standing. Also partners have provided an escalation path should any issues be identified. Acquisition of AMT-SYBEX by Capita and change of resource at KiwiPower raised as separate risks. Poyry notified of a resource change in October 2014 but working contact remains engaged. S&C Electric management team has changed, but new contacts introduced and engaged.
R0044	G	Lack of clear scope/requirements for Partners result in scope creep and delays.	During scoping/design phase ensure all elements of work are captured through engagement & 'sign off' from key internal stakeholders.	Further product Descriptions to be completed and approved for partner-led work and reports.
R0045	G	Partners do not have a clear delivery plan, which will result in delivery delays and missing milestones.	Partners are involved in producing a project plan and monthly reports to track progress. Payment for any works will be linked to its completion on time to cost and quality.	Partners are involved in producing a project plan and monthly reports to track progress. Payment for any works will be linked to its completion on time to cost and quality.
R0046	Closed	Building redesigns mean overspend on WS 1.	Ensure close collaboration between storage supplier and Capital Programme directorate to ensure planning app reflects requirements.	Risk closed: Build has now finished. Some overspend has occurred, within project contingency.
R0051	G	Partner spend is higher than anticipated.	Overspend on project studies or services.	Monthly account reconciliations and forecast undertaken to understand financial reporting. Any deviations on forecast or unexpected elements will be reported or escalated as necessary.
R0053	G	Partners may have concerns about the level of resource they need to dedicate to the project. The risk is that partners withdraw involvement, leading to delays or additional costs to mitigate.	Make contingency available for additional partner costs. Provide update to partners in forums on expected upcoming resource needs.	Remain sensitive to time draw on partners where there is no funding Resource forecasts have been provided to project partners for improved forward visibility.

Ref No.	RAG Status	Risk & Impact Description	Mitigating Actions	Update
R0057	G	Budget restrictions mean that the design process is not as comprehensive or exhaustive as it could be, leading to issues or delays later in the lifecycle.	Ensure good engagement with subject-matter experts, keep well documented design discussions and conclusions, attempt best-practice within the constraints of our budget.	Design Assurance sign off achieved 30 September 2013 as part of SDRC 9.1. Subject matter experts will continue to assist through commissioning. Budget restrictions did not materialise but some time restrictions did