Enhanced Frequency Control Capability (EFCC)

National Grid

Battery Storage Investigation Report - June 2015

Table of Contents

Executive Summary

The purpose of this report is to provide the summary of the investigation into the use of existing battery storage facilities for the Network Innovation Competition funded project; Enhanced Frequency Control Capability (EFCC). As part of this investigation, National Grid carried out the following activities; starting from December 2014:

- Further reviewing the battery storage technologies suitable for demonstrations of fast frequency response in the EFCC project (in addition to the previous work carried out before submission of EFCC proforma to Ofgem);
- Engaging with the owners of these battery storage facilities which their technology was deemed to be suitable for providing fast frequency response;
- Carrying out site visit, request detailed implementation cost, timeline, and explore the technical and commercial aspects of use of one of those facilities; and
- Carrying out an impact assessment; taking into account the overall cost to the project, project delivery risk and value to consumers.

The main findings of this exercise include:

- There are limited number of already installed battery storage facilities which are suitable for providing the fast response, namely: Leighton Buzzard, Rise Carr (Darlington), and Willenhall.
- The main challenges of using the existing sites include significant delays in delivering the EFCC project, expensive modifications costs (in case of Leighton Buzzard it will be more expensive than use of the new battery storage), and potential future costs that were not possible to clarify at this stage.
- More importantlyt, the inability to perform the demonstration of fast response capability of renewable energy resources combined with battery storage (hybrid) as proposed in this project, should we decide to use an already installed battery storage unit.
- The hybrid battery storage and renewable generation (solar PV) will be the first demonstration of such concept in Great Britain, and will generate significant learning on the system benefits in the context of the System Operability Framework, and Future Energy Scenarios.

As more renewable energy connects to the transmission system the System Operator will require frequency response from a wider range of resources. On the balance of cost, project implementation risks, and value for money for our consumers, we therefore recommend the use of a new battery storage for the EFCC project. This investment will enable the project to proceed with demonstrations that integrate renewable energy with battery storage needed for future frequency control capability, and allow the realisation of EFCC objectives so full cost savings can be passed on to consumers.

Chapter 1 Purpose of this report

In order to meet carbon reduction targets, GB needs to significantly increase the volume of low carbon energy technologies that are connected to the GB transmission system. The overall impact of increasing these types of technology will be a reduction in system inertia.

System inertia is a characteristic of an electrical transmission that provides system robustness against any frequency disturbances and is a result of the energy stored in the rotating mass of electrical machines i.e. generators and motors.

As more renewable energy technologies such as wind, solar PV and other convertor based technologies (e.g. interconnectors) are connected to the transmission system, there will be a corresponding reduction in inertia since these technologies do not contribute to natural mechanical inertia.

In the GB the transmission system, frequency is nominally 50Hz and the System Operator caters for various imbalances caused by changes in demand or generation to maintain the frequency in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS). However, the lower the system inertia, the more susceptible a transmission system is to a higher rate of change of frequency (RoCoF) in the event of the loss of a significant volume of generation or demand and requires an increase in the speed and volume of frequency response.

The EFCC Project Full Submission report (October 2014), provided cost benefit analysis to show that under existing mechanisms to control frequency response used by National Grid, the future increase in response requirement to control frequency is anticipated to be £200m-£250m per annum by 2020. This cost is based on the Gone Green Future Energy Scenario as published by National Grid in 2014 that gives rise to an increase in RoCoF of 0.3Hz/s.

As set out within the EFCC Full Submission report, within Work Package 2.4, a proposal was put forward to trial battery storage as part of a portfolio of service providers for fast frequency response. The proposal included provision for investment in a new battery storage unit (plus two inverters for increased active or reactive power). Costs were included for trials to be carried out at two different locations, one of which would allow for combining battery storage with a solar PV plant.

Beletric where chosen as a project partner for the provision of battery storage and solar PV power plant for frequency response within EFCC through a competivive tender process in line with all partner selections against set criteria. These criteria included cost and contribution to ensure value for money; organisation to rate reputation and expertise; understanding of project requirements and the ability to deliver; offered solution that is innovative, low carbon, brings customer benefits and learning.

Belectric has developed, planned and built a number of hybrid projects where various energy sources are combined and controlled, including PV, batteries, diesel and water power generators. For the EFCC bid they provided detailed cost estimates that were verified and reviewed through a thorough internal review process that included National Grid procurement and finance departments.

Chapter 1 Purpose of this report

A new battery storage facility represented a significant proportion of the EFCC project costs (approximately £1.1m). However, due to the containerised unit provided by Belectric, trials could be undertaken at Redruth in Cornwall and Rainbow Solar Farm (3.8MWp) in Gloucestershire. This will enable trials to be carried out at a location on the GB transmission system known to be susceptible to operability challenges (Redruth) as well as gaining valuable learning from the battery unit sited at Rainbow Solar Farm.

However, to ensure EFCC represents the best possible value for consumers in advance of any expenditure, a Decision Point was included within the project timescales to allow National Grid to investigate the use of existing battery storage sites within the UK.

This report details the outcomes of investigations considering technical and commercial implications of using existing facilities within the EFCC project as well as impact on timescales. Comparison and cost benefit analysis is presented between those sites deemed most appropriate for use for fast frequency response versus the installation of an additional battery storage facility. Furthermore, the benefits of the a hybrid solar PV and battery storage solution is presented.

Finally, a recommendation is proposed that establishes and quantifies the benefits, potential learning within EFCC and value to consumers to enable Ofgem to determine if investment in further battery storage should be made.

Chapter 2 Use of Battery Storage within EFCC project

The objective of the EFCC project is to develop and demonstrate an innovative new monitoring and control system which will obtain accurate frequency data at a regional level, calculate the required rate and volume of very fast response and then enable the initiation of this required response. The control system will then be used to demonstrate the coordination of fast response from wind, large scale thermal generation, demand side resources (DSR), solar PV and battery storage. Utilising the output of these trials, a fully optimised and coordinated model will be developed which ensures the appropriate mix of response is utilised. This will support the development of an appropriate commercial framework at the end of the project.

Figure 1 below shows indicative GB regional zones for regional control and the proposed Alstom scheme to monitor wide area frequency measurements and control the response providers.

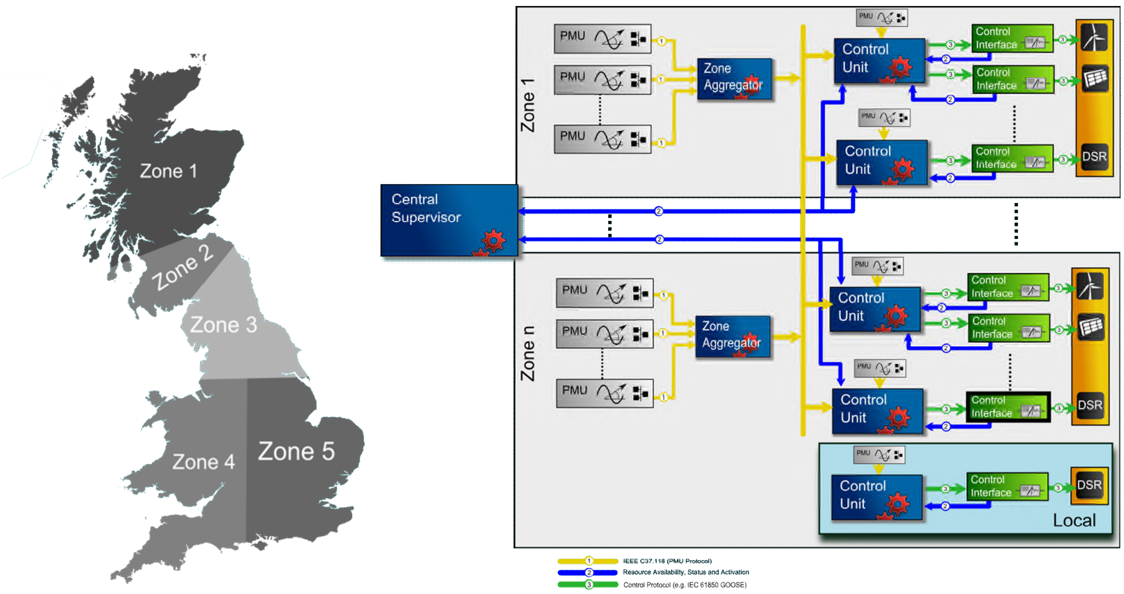

Figure 1: Control System Architecture

Battery storage is regarded as a central part of the fast services to be trialled within the EFCC project. Previous studies and practical solutions have demonstrated that battery storage is able to provide fast and sustained response on various networks to maintain stability. Connected to the wide area measurement of Alstom, the battery shall provide fast and local frequency response, based on central and locally derived response signals. The goal is to counteract local frequency deviations in order to neutralise them before they become a major disturbance. This has to be done close to the source of disturbance and in a timeframe of well below 100ms, since this is the typically measured time of such disturbances. The battery response trials shall be based on:

Chapter 2 Use of Battery Storage within EFCC project

- Maximum response to curtail reduction in frequency. Trial the fastest possible rise and sustained response until frequency is restored or stored energy is used.
- Frequency following (Proportional Control; output in response to variations in frequency). This response could be enabled locally and controlled.
- Setpoint following initiated from a remote signal in combination with other response providers. This mode could be used by the monitoring and control system to sustain a frequency response.

In addition, a further trial could be to use historic data (i.e. over the previous few miliseconds) to predict upcoming frequency drops.

While the above is a way of frequency stabilisation by actively responding to a measured signal ("active response"), there is as well, a passive response which is crucial for grid stability: the grid inertia. Grid inertia is traditionally supplied by the rotating mass of synchronous generators. Due to increasing penetration levels of renewable energy in the network, the share of synchronous generation is dropping rapidly as well as inertia. The reason behind this is lack of inertia of the physical generation source (e.g. solar PV panel in case of solar energy and of the grid coupling inverter). There is simply no mass turning. A battery – on the contrary – is capable of simulating inertia, since it may provide a very high short circuit power. Given that this is combined with a fast reacting inverter, it may provide a "virtual inertia" by very fast active control (<20 ms). In this way it may replace the inertia traditionally supplied by synchronous generators and shall be trialled during the project.

The Main Drivers for using battery storage

- Demonstrate the principle operability of a frequency control battery on the network.
- Demonstrate different reaction speeds.
- Demonstrate emulation of rotating generators and their inertia by implementing a very high response rate (milliseconds or tens of milliseconds).
- A direct connection to an external entity (i.e. the NETSO) shall be established, so definition of working points, response statistics or direct command and control may be done from a central point outside the unit.

Innovation and Learning Outcomes

- Innovative command and control schemes will be implemented that enable the battery to act similar to rotating machines, providing short-circuit power capacity, and respond to external control signals.
- Evaluation of the challenges of incorporating batteries in network regulation (e.g. various States of Charge) and their advantages will be studied.
- The financial benefits of operating a battery in the plant will be studied and the development of a future financial compensation and commercial policy for battery operation will be outlined. This will provide a vital new tool for National Grid as we continue to manage the GB system.

Chapter 2 Use of Battery Storage within EFCC project

- Allow a fuller assessment of the potential for greater competition in frequency response service provision that can inform other Transmission Licensees.
- Demonstrate battery storage can best be coordinated to provide an optimised response across a range of resource providers.
- The response capabilities of new technologies are not currently being fully utilised. With the increase in the amount of renewables connected to the GB electricity system, it is vital that a more diverse range of resources are able to contribute to system stability in a more economic and efficient way.
- Potential for knowledge of the capability of batteries and solar PV power plants in delivering grid services on different levels.
- Support the development of performance requirements for roll out of an Enhanced Frequency Control Capability as a new balancing service.

Impact of Future Energy Scenarios on system operability

Annually National Grid publishes four future energy scenarios that outline possible variations in generation and demand patterns. Last year under the Gone Green scenario, predicted that in meeting the UK renewable energy targets, solar PV would contribute 2.3GW of installed capacity by 2020.

The connection of embedded generation is increasing rapidly in GB. Due to it's lower operational voltage these installations are connected to Distribution Network Operators (DNOs), hence it's output will offset the total demand seen at the interface boundary between the transmission and distribution systems.

In order to maintain the system frequency within statutory limits, the System Operator must balance generation and demand. However, as the volume of intermittent generation sources grows, the demand seen by the transmission system will become increasingly volatile and pose challenges in predicting demand and therefore operation of the transmission system.

Figure 2 below, shows an average demand profile for an average Sunday in July for the Gone Green future energy scenario. Historical data has been obtained between 2005 – 2008/9, excluding the impact of embedded generation and has been scaled against the summer minimum demand values to produce a base demand daily profile. Planned solar daily profiles have been derived from average output profiles and scaled to 84% of capacity (14GW). The resultant transmission demand profile is offset by the solar output. Between the dotted line, illustrating the natural load, and the hard red line of the planned embedded solar case there is some 18GW of difference over the course of a day.

Chapter 2 Use of Battery Storage within EFCC project

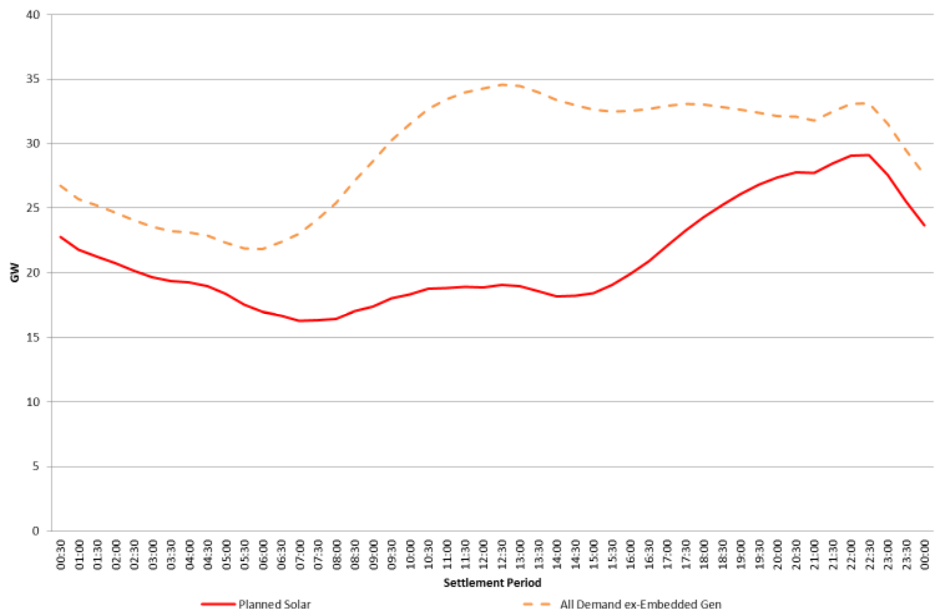

Figure 2: Impact of increasing solar PV on the transmission demand pattern (2020)

Against such declining demand levels, there is a danger that in particular regions of the network where there is high concentration of solar PV, there is potential for parts of the network to be disconnected. This could arise when there is a frequency excursion that triggers LFDD (Low Frequency Demand Disconnection) which is an operational method used to correct the imbalance between generation and demand. If LFDD action occurs, the network could represent negative demand and further contribute to any frequency disturbance which takes the system beyond normal frequency containment limits.

In addition to managing the system with increasingly volatile periods of transmission demand, solar PV is connected to the system via power electronics and therefore does not provide inertia. As mentioned in Chapter 1, this means that a system with lower inertia will be susceptible to high RoCoF necessitating increased frequency response to be held by the System Operator. Historically to operate the system in low demand periods, generation is constrained and interconnector imports restricted. However, as a greater proportion of generation is supplied from intermittent sources, more frequency response will be required from alternatives to conventional generation such as those being trialled in the EFCC project.

An alternative approach is to combine solar PV with battery storage. This will allow storage to be used to better regulate or smooth the transmission demand profile or be used to provide response during periods of rebalancing as other conventional plant ramps up to provide a sustained response to maintain frequency within limits.

Use of batteries would offer the flexibility either to reduce the effective generation contribution to the distribution system which is observed at these times of stress, or to provide additional fast response to support frequency containment under high RoCof events, instead of reliance upon the natural inertia of (slower responding) conventional generation or LFDD action.

Chapter 2 Use of Battery Storage within EFCC project

International Experience

In Germany renewable energy contributes significantly towards their total generation capacity. It has been recognised that due to the higher volatility of generation and demand patterns, battery storage can play an active part in smoothing this volality as well as providing fast frequency response. The four German TNOs, Tennet, Amprion, Transnet BW and 50Hertz have enabled renewables to participate in the frequency reserve market by changing their bidding/procurement timescales and established prequalifying criteria to fully benefit from the potential combining solar and battery plants to ancillary services.

Last year in the US, the State of California passed legislation mandating that energy storage facilities be installed to support the integration of additional solar and wind energy in order to meet their utility owned energy storage target by 2020 (approximately 1.3GW)[6]. It is the first state to do this, but is recognition that storage systems can support the uptake of renewable technology connected to utility networks in addition to providing stand alone peak load reduction, voltage support and frequency response services. As an example of this uptake, Invenergy (developer of clean power generation and energy storage projects) has installed a 31.5MW battery storage in central Illinios which is located near a wind farm project and solar plant to provide fast frequency response as well as other ancilliary services [7].

Furthermore, in order to integrate more wind energy into an island system in Alaska, the electricity utility installed a 3MW battery storage system instead of connecting more diesel generation as spinning reserve. In addition to mitigating the curtailment of energy from wind farms, the lead-acid battery system is capable of providing frequency response within 0.5s if required [8].

The Zhangbei National Wind and Solar Energy Storage and Transmission Demonstration Project includes a total of 17MW/70MWh of energy storage through a combination of lithium-ion and vanadium redox flow battery technologies. The use of batteries supports the integration of wind, solar and other renewable energy providing frequency regulation and voltage support to the grid [12].

Chapter 3 Evaluation of existing battery storage in the UK

As a starting point for evaluating existing storage facilities for potential use with the EFCC project, information was collected using the Energy Storage Operators' Forum published documentation. In addition, a general enquiry was sent to all Distribution Network Operators (DNOs) that currently have demonstration battery storage facilities or are due to install battery storage within the timescales of the EFCC project. The email outlined our objectives, the reasons for the enquiry and the possibility of participating in the project. In addition, a technical questionnaire was compiled and attached to the enquiry to provide DNOs with information that the EFCC project would like to assess.

A full list of energy storage sites and associated technical criteria that was compiled from documentation within the public domain as well as individual site specific details provided by DNOs. This is shown in Appendix B.

From the initial information gathered, it was possible to eliminate a number of existing storage sites for suitability for inclusion within the EFCC project based on the following criteria

1. Battery technology.
   Flow type batteries as demonstrated at Nairn, FALCON and the DECC Energy Storage demonstration sites[2] were excluded on the basis that they will not provide the required fast <0.5s response times to be trailed. Due to the time taken for electrolytes to mix that is inherent with this technology to produce a change in power output, fast response times cannot be achieved. Additionally, the power to capacity ratio of these batteries is not favourable for short-term, high-power applications that is being trialled in the EFCC project.

2. Power output and Capacity
   It is preferable for the battery unit to have a high power output so it will increase its contribution to alleviating significant RoCoF by increasing or decreasing larger amounts of power. Essentially for rapid frequency response it is beneficial to have more power delivered at less installed capacity.

3. Connection to the system
   The battery unit must be connected to the electricity network, hence units sited in the Scottish Highlands that maintain security of supply could not be utilised for the project.

Timescales for EFCC trials

Within the EFCC project submission, the project plan outlined the installation and evaluation of a new battery control system between October to December 2016 for integration with the Alstom monitoring and control system. This is in advance of frequency response trials taking place from January 2017 to September 2017.

Short-listed battery units

Three sites were chosen for further investigation as possible candidates for participation in the EFCC project. These sites are Leighton Buzzard (6MW, 10MWh, Lithium Nickel Manganese Cobalt Oxide), Darlington (2.5MW, 5MWh, Lithium Iron Phosphate), Willenhall (2MW, 1MWh, Lithium-Titanate).

The respective DNOs (UK Power Networks, Northern Power Grid, Western Power Distribution and) were approached in order to discuss the viability of using these storage sites.

Chapter 3 Evaluation of existing battery storage in the UK

Smarter Network Storage (SNS) at Leighton Buzzard

The Smarter Network Storage (SNS) project at Leighton Buzzard is an LCNF project that is to explore multi-purpose use of battery storage from a technical and commercial perspective. The main driver for battery storage at this site was to defer traditional reinforcement in order to maintain demand security compliance at Leighton Buzzard, but the project is also trialling the provision of commercial ancillary services to the transmission system.

Representatives from Belectric and National Grid attended a site visit to Leighton Buzzard to further understand the battery and inverter technologies, how the site is controlled as well as the future operational timescales within the lifetime of the project. One outcome from the visit is that it is unclear if the control system can be modified to allow rapid response as per EFCC objectives.

The storage system is fully contained within a dedicated building adjacent to Leighton Buzzard substation in Bedfordshire. The building also houses separate inverter and control rooms.

The battery size (6MW, 10MWh Li-NMC, Lithium Nickel Manganese Cobalt Oxide) offers a power/capacity ratio of 0.6. There are 3 sets of 2MW battery stacks that are controlled by dedicated energy storage management units that are contolled locally by a central control system that can be accessed remotely. There is a forecasting and optimisation system for scheduling services which can be enabled via a control room so there could be the possibility of trialling both local and remote frequency response for EFCC. Overall, the speed of response will depend on the initiation being local or remote. It is anticpated that the response time could be less than half a second but it is more likely that the response time will be between 0.5s and 1s. The EFCC project is aiming for a target response time of 0.1s.

SNS is currently trialling frequency response provision under National Grid's existing ancillary services (using a demand side aggregator), hence trialling with EFCC fits within their scope of objectives.

The SNS project is due to complete in its entirety by December 2017 and it is the intention of UK Power Networks to complete all their scheduled trials by December 2016. Given this, there is not an exact alignment of timescales between the projects, and there is some risk that the trial period for SNS could be extended in order to meet their project milestones.

UKPN has provided estimated costs for using SNS within EFCC. These are summarised in Chapter 5 (Commercial Analysis of short listed sites) of this report. In addition, UKPN will be entering into commercial contracts for the provision of ancillary services. The Commercial team in National Grid has estimated a cost for these services that could be paid to UKPN in order to compensate for loss of revenue during the trial period.

Chapter 3 Evaluation of existing battery storage in the UK

Image 1 (coutesy of UKPN): Smarter Network Storage (SNS) at Leighton Buzzard (6MW, 10MWh, Li-NMC).

Image 2: Site visit to SNS at Leighton Buzzard

Rise Carr (Darlington)

Northern Power Grid (NPG), as part of their Customer-Led Network Revolution LCNF project, installed a 2.5MW/5MWh LiFePO4 (Lithium Iron Phosphate) battery, unit at Rise Carr to investigate how a battery can be used to facilitate the uptake of low carbon technologies.

Chapter 3 Evaluation of existing battery storage in the UK

The project completed in December 2014 and currently NPG is considering future research and commercial opportunities for the battery storage unit. In discussions with NPG, participating within the EFCC project is being considered as an option, and a decision on the future utilisation of the battery is expected summer 2015. At time of writing, the EFCC project is awaiting this outcome however, NPG has stated that the Rise Carr site is likely to be used for commercial ancillary services as well as local demand support. Indication has been given that these commercial services could be suspended for use within EFCC although this is to be confirmed.

The Rise Carr is built up of three separate shipping containers, 1 x Inverter section and 2 x Battery Rack Containers and offers a power/capacity ratio of 0.5. Similarly to SNS, it can be controlled both locally and remotely (including monitoring status and alarms, overall system data etc). This is achieved through dedicated software that can used via a web browser. For remote control the communication time is given as 20ms so a fast ramp response can be achieved in less than 100ms which is the target response time for EFCC.

Estimated costs for its use within EFCC have been provided and these are summarised below in Chapter 5 of this report. There is a possibility that NPG will undertake other trials or even participate in the ancillary services in advance of the outlined trial period for EFCC. If this occurs, for the duration of the EFCC trial period, it is likely NPG will have to suspend its ancillary services activities and possibly compensated for loss of revenue. These services are bilaterally contracted and since negotiations have not commenced, it is not possible to incorporate an allowance. This cost exposure poses a risk for the EFCC project.

Image 3 (courtesy of NPG): Battery storage unit at Rise Carr, Darlington

Chapter 3 Evaluation of existing battery storage in the UK

Willenhall

A 2MW/1MWh Li-Ti (Lithium-Titinate) battery unit is due to commission at Western Power Distribution's Willenhall substation at the end of July 2015. This is an EPSRC funded project to investigate the characteristics of Li-Ti (this is the first battery of this type to be trialed in the UK), how different battery chemistries can work together for grid use and the coordination of large storage with EV (2nd life) batteries. The project is being managed by the University of Sheffield who will be carrying out research studies on Li-Ti cell degradation and integrating battery characteristics. Aston and Southampton Unversities are also involved in the project looking at the optimum use of 2nd life EV batteries and vehicle to grid research.

The battery is housed in a containerised unit sited on land leased from WPD. It has a power/capacity ratio of 2 which is more favourable than the other sites for fast frequency response. There is a dedicated management system that has a localised control interface, and in addition the University of Sheffield has developed a bespoke remote control system that separately controls the battery management system and the inverters. In this respect, any Alstom frequency control system for EFCC will have to be integrated with the University of Sheffield system to enable frequency response demonstrations. It is anticipated that a fast ramp response in line with the target response of 100ms for EFCC can be achieved.

Funding for the project has provided the battery unit, inverters and associated assets for the connection only. This is a purely research based project whereby the University of Sheffield is endeavouring to gain as much learning as possible throughout the lifetime of the battery (guaranteed for 10 years). As such, they are seeking interest in projects that could further the understanding of how Li-Ti operates, although the provision of grid services is not the primary objective.

Estimated costs for use within EFCC have been provided and are summarised in the Commercial Analysis section of this report. At time of writing, access to the battery for the EFCC project is available from October 2016 (for control system modifications) through to the end of the proposed trial period at the end of September 2017. Costs are associated with University staff and contractor resource as there is no commercial cost exposure for EFCC as the Willenhall project is for research purposes only.

Image 4 (courtesy of The University of Sheffield): Willenhall battery unit

Chapter 4 Belectric Energy Buffer Unit (EBU) Battery Storage

The Belectric solution consists of a 40” containerised high power lead acid battery, that is optimised for frequency regulation. It features a capacity of 948kWh and a deliverable power of 700-1400kW depending on time and inverter configuration. The same battery type has shown to last 7000 full cycles in frequency regulation (BEWAG battery, Berlin 1986-1994) and has been integrated into a scalable and easily deployable stationary system using the technological advances of the last 20 years. The system is equipped with air conditioning and a powerful external venting for continual high power applications, with automatic water refilling, electrolyte mixing and cell detailed battery monitoring system to facilitate maintenance and remote operation. In addition it features a safety system for hydrogen venting and charge control as well as an operating system which includes operation, battery management and data provision (e.g. State of Charge, currently available power, remaining total battery capacity) linked to a central SCADA system. It can be operated remotely and has the same local and remote interface.

The battery system (developed from solar applications) is coupled to a GE based inverter skid in an outdoor confirguration complete with 11kV or 33kV transformer.

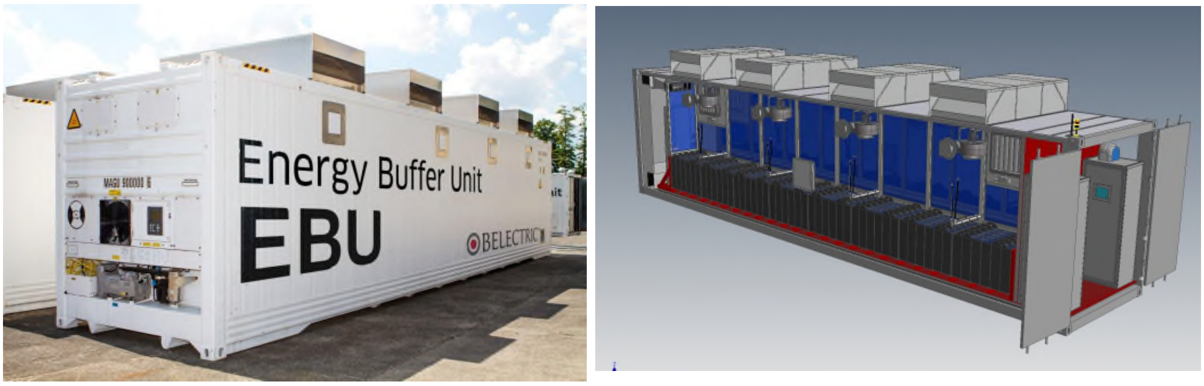

Image 5 (courtesy of Belectric): Energy Buffer Unit (EBU) battery storage

The inverter and the control system have been optimised for fast response times. Inverter based control schemes such as virtual inertia and frequency generation, feature a reaction time less than 20ms. Control schemes invoking the operating system (frequency response, central command response) feature a round trip time of under 100ms due to stringent loop time control and a real time interface between control system and inverter.

Chapter 4 Belectric Energy Buffer Unit (EBU) Battery Storage

Image 6 (courtesy of Belectric): EBU (battery storage) with inverter installation at Alt Daber, Germany

As the battery unit is containerised it can be relocated to further provide economises within the project. Belectric has nominated two different sites (Rainbows Solar Farm, in Gloucestershire and Redruth in Cornwall) where the battery can be sited during the project.

The two different locations for the battery unit were put forward as part of the EFCC submission for separate reasons. The Redruth site was proposed in order to demonstrate independently how the EBU can provide fast frequency response in a part of the network where there are existing challenges in maintaining system stability. This will allow optimising of the Alstom monitoring and control system in conjunction with this response provision in a known constrained part of the network.

Conversely, Rainbows Solar Farm was nominated to demonstrate how solar PV plant combined with battery storage can provide additional learning for rapid frequency response. This is discussed further later in this report in Chapter 6 “Opportunities for combining solar PV and battery storage in EFCC”.

Future use of potential Belectric Battery Unit

If a new Belectric battery unit (EBU) is to be used in the EFCC project, consideration must be given to it’s ongoing use for the lifetime of the installation.

As mentioned in Chapter 3 “Evaluation of existing battery storage in the UK”, the rapid frequency trial period is due to complete at the end of September 2017, which gives sufficient time to carry out knowledge dissemination in advance of project closure at the end of March 2018.

The proposal for use of the EBU would be to participate within the new fast frequency commercial framework to be developed by the EFCC project. The EBU would also be able to provide a range of ancillary services to National Grid through existing mechanisms to assist in system stability.

Moreover, the system would be made available for further research activities to provide knowledge of the viability and capability of the system.

Chapter 5 Commercial Analysis of shortlisted storage units

The analysis below outlines the cost estimates associated with using existing battery storage units at Leighton Buzzard, Darlington and Willenhall. The base costs shown have been agreed with the respective DNOs or in the case of Willenhall with the University of Sheffield. These costs are commercially sensitive and as such will only be included in the report submitted to Ofgem and with the not be made public.

As previously described in Chapter 3, SNS at Leighton Buzzard is due to enter into commercial contractual arrangements with National Grid for frequency response. It is anticipated that during the trial period for EFCC, SNS will not be able to fulfil these arrangements therefore the EFCC project will need to reimburse their potential loss of revenue. Due to commercial sensitivity with differing frequency response products that are negotiated, it is not possible to publically specify the contract terms (e.g. price per MWh or time of use etc). The Commercial Services department at National Grid has estimated the cost of these services outlined in the report to Ofgem.

Similarly, the battery unit at Rise Carr may also need to be compensated for loss of revenue if they enter into commercial contracts for frequency response but this is yet to be determined.

The engineering costs shown below for the existing battery storage sites include labour costs for modifications to control and IS systems for the estimated 3 month period as set out in the schedules in the EFCC Full Submission. Additionally, for some sites, consideration is given to warranty extensions. It must be noted that these are high level estimates that are likely to change and be subject to site surveys and further investigations to be undertaken during the project. The cost breakdown for each site is outlined in the sections below.

Cost summary for Smarter Network Storage (SNS)

	Cost (£k)
Commercially sensitive information	
Additonal project management	150
Alstom additional project management cost including engagement with new project partner	100
PROJECT TOTAL	**1169**

Table 1: Cost of use for SNS at Leighton Buzzard for EFCC

Chapter 5 Commercial Analysis of shortlisted storage units

Commercially sensitive information

- Operational Telecoms resource (to cover any design or mods to communications systems)
- IS Architectural resource (to cover any design or mods to existing system architectures)
- RTU / ENMAC integration technical resource (to cover any design or mods to SCADA systems)

Commercially sensitive information

The contingency estimate is based on half of total engineering design contractor costs (i.e to account for uncertainty in carrying out the modifications as it is unclear the extent required). It will also cater for any additional expenditure prior to installation of control equipment, or additional commissioning requirements during the frequency response trial period.

Cost summary for Rise Carr (Darlington)

Commercially sensitive information	
Additonal project management	150
Alstom additional project management cost including engagement with new project partner	100
PROJECT TOTAL	**444**

Table 2: Cost of use for Rise Carr at Darlington for EFCC

Chapter 5 Commercial Analysis of shortlisted storage units

The category for “Other Operation & Maintenance costs” include maintenance, communications, engineering support and future provision for battery cell replacement. The NPG engineering resource includes installation and control engineering, commissioning and some project management costs. Similarly, contract engineering has been estimated for design, commissioning and project management activities.

NPG has provided a full breakdown of these costs with estimated time to be taken for each activity as well as daily rates for each resource; this is shown in Appendix C.

It is to be noted that the base cost as provided by NPG is a budget estimate for the use of Rise Carr within the EFCC project.

Cost summary for Willenhall

	Cost (£k)
Commercially sensitive information	
Additonal project management	150
Alstom additional project management cost including engagement with new project partner	100
PROJECT TOTAL	**483**

Table 3: Cost of use for Willenhall for EFCC

As mentioned earlier in the chapter, the battery unit at Willenhall is for research purposes only, resulting in a lower potential cost of use, and therefore does not require compensation for lost revenue associated with commercial services provision.

Chapter 5 Commercial Analysis of shortlisted storage units

Cost Summary for Belectric Energy Buffer Unit

	Cost (£k)
Site preparation	14
Battery unit plus 1 inverter	520
Second inverter (to provide higher power)	96
Electrical equipment modifications at Rainbows solar PV plant	70
Electrical equipment connection at Redruth	128
IT and communications systems	24
Contingency	186
BASE TOTAL	**1100**
Additonal project management	0
Alstom additional project management cost including engagement with new project partner	0
PROJECT TOTAL	**1100**

Table 4: Summary of battery storage cost of use within EFCC

As mentioned in Chapter 3 “Evaluation of existing battery storage in the UK” the total cost for the Belectric solution includes provision to mobilise the battery storage unit at Redruth and Rainbows Solar Farm. There are no additional project management costs as these have already been accounted for within the project.

The detailed cost breakdown as provided in the EFCC Full Submission Document is shown in Appendix D.

Summary

Table 5 below summarises the capability of each site for rapid frequency response, the total cost of use for each site, and the viability of inclusion within EFCC project timescales.

Chapter 5 Commercial Analysis of shortlisted storage units

	Capability for rapid frequency response for EFCC	Cost of use (£k)	Inclusion of compensation for commercial services	Availability/ Timescales for EFCC	Additional learning for EFCC (hybrid-renewable & storage)
SNS (Leighton Buzzard)	Likely(1)	£1169	Yes	Uncertain	No
Rise Carr (Darlington)	Likely(1)	£444	No	Uncertain	No
Willenhall	Likely(1)	£483	Not Applicable	Uncertain	No
Belectric	Yes	£1100(2)	Not applicable	Yes	Yes

Table 5: Summary of battery storage cost of use within EFCC

(1) The control system changes and integration into the EFCC control system is the uncertain element at this stage
(2) Cost includes site preparation, installation of new battery unit, inverters and relocation of battery system

For the SNS project due to the existing control system configuration, there is uncertainty whether even after the integration of the Alstom control and monitoring system, the target response for the project can be realised. It is an ongoing innovation project and as such has its own specific objectives that must be met. There is a risk to the EFCC project that fast frequency response trials will be delayed if SNS objectives take priority over the EFCC project.

In the case of Rise Carr, at time of writing, there is uncertainty whether NPG will allow their site to participate in the EFCC project. There is the possibility of obtaining rapid frequency response, though again, the extent of control system modifications may negatively impact the EFCC project as it is likely that the site will have ongoing commercial activities. Furthermore, there may be an additional cost exposure for compensation for anciliary services. At this stage it is not possible to quantify what the anciliary service cost may be as commercial contracts are not in place.

Both SNS and Rise Carr sites have lower C-rates (power/capacity ratio), that will not provide the opportunity to trial low capacity/high-C-rate installations in order to obtain the full potential of rapid frequency response and hence optimise the future value of rapid frequency response provision.

With respect to Willenhall, it has a more favourable C-rate it is anticipated that the target response to RoCoF can be achieved. At time of writing, the University of Sheffield is actively seeking research opportunities. Like the SNS project, it has specific objectives and other projects may be agreed upon during the determination process that may not align with the EFCC project timescales.

For the Belectric solution, some discussion has taken place within the EFCC project so far, leading to there being greater clarity regarding the control system interfaces between Belectric and Alstom which reduces this risk. Moreover, since this would be a new installation the risk for access to carry out modifications and carry out trials is mitigated.

Chapter 5 Commercial Analysis of shortlisted storage units

The information gathered has shown that currently there is a limited portfolio of energy storage technologies that are capable of providing fast frequency response. The three existing storage sites that have been shortlisted all utilise Lithium Ion batteries. Allowing the installation of a lead-acid battery unit provided by Belectric will provide valuable knowledge and learning from this technology in the area of fast frequency response. It will also demonstrate to the wider industry that other battery technologies can be utilised for fast frequency response and potentially other future ancillary services.

Only the installation of a Belectric battery unit will allow the full realisation of combining renewable generation (solar PV) with battery storage to trial their full potential. The battery unit can also be relocated to two different locations to provide increased learning of differing site and network conditions within the EFCC project.

The cost benefit analysis included in the full EFCC project submission showed that under the Gone Green future energy scenario, by 2020 and with the implementation of the EFCC project, the potential cost saving to consumers would be approximately £200m per annum. The investigations of existing battery storage units has shown that the estimated cost of additional learning that can be achieved through investment in battery storage plus solar PV is in the order of £69k to £656k. Only with this investment can the full realisation of EFCC objectives be achieved and therefore the full cost savings passed on to consumers. This is explored further in next chapter.

Chapter 6 Opportunity for combining solar PV and battery storage in EFCC

In the UK, there is ongoing work with innovation projects to allow battery storage resources to be used for the provision of ancillary services to support the electricity system. This may lead to the emergence of new commercial frameworks to allow storage to participate wthin existing commercial markets.

However, the EFCC project is seeking not only to generate a new rapid frequency response mechanism from non-conventional resources, but to understand and fully realise their full potential in providing cost savings over conventional services.

Chapter 2 discussed how significant amounts of solar PV connected to the network is offsetting the transmission system demand profile, and due to it's variable output, makes maintaining the generation and demand balance (hence frequency) more challenging. Furthermore, solar PV does not provide natural inertia to the network. Battery storage can be used to alleviate the power imbalance and provide fast frequency response when required. The EFCC project seeks to realise by demonstration through the project, the benefit of combining battery storage with solar PV.

Trials for Solar PV and Battery Storage

The combination of solar PV and battery technologies will provide an opportunity to expand the scope and therefore the learning outcomes over and above rapid frequency response trials for battery storage alone. In order to increase the leverage and to reduce cost of frequency control, the battery-based response shall be supplemented by PV-based response. For overall frequency control the battery needs to be capable of providing equal response in either direction: positive and negative. This means, the battery needs to be at a state of charge (SoC) of around 60% in order for it to have the capacity to be charged and discharged at equal rate and for equal time. Locally combining the battery with a response provider who might deliver negative response (by power curtailment) allows the battery to raise its state of charge up to 95% and therefore provide more positive response for a longer period of time (at the same time neglecting the negative response which is taken over by the PV power plant). Provided this integration takes place on the same site, communication will be sufficiently fast and failure rate will be sufficiently low in order to provide response at an acceptable reliability. A combined system of this kind will significantly increase the value of a battery for the system operator with negligible addition of cost (cost of curtailed PV energy). The value of this could be trialled during the project. Hence the following can be undertaken

1. Work out operational scheme for lowering and raising SoC of the battery to comply with the actual capability of the PV power plant to deliver negative response (corresponding to current level of irradiation i.e. PV power.

2. Optimise the response distribution between battery and solar PV e.g.

   - Battery provides 100% of battery positive response, 0% of negative responses from 95% SoC (State of Charge).
   - Battery provides 100% of battery positive response, 50% of negative responses from 80% SoC (State of Charge).

   The objective is to have an optimal operation scheme minimizing the cost of PV power curtailment and at the same time maximising the value of the battery as a response provider.

3. Integrating a variable response unit into grid management.

A battery based frequency response unit has an efficiency typically in the range between 80% and 90%. The corresponding losses during battery operation have to be replaced by an external source. This may well be done by the production of the adjacent PV power plant - especially, if the latter is currently curtailed due to distribution network limitations.

Belectric Contribution with solar PV and battery storage

Belectric provides utility-grade PV power plants that enable safe, reliable, and efficient power generation and proven experience with incorporating PV plants and battery storage for frequency regulation.

Rainbows Solar Farm 3.8MWp near the village of WIllersey in Gloucester is currently operated by Belectric. This site (also known as Willersey Solar Farm) has been nominated as a potential site where the EBU and associated equipment can be installed in order to demonstrate how solar PV and battery storage can provide additional learning for rapid frequency response in the EFCC project.

Chapter 7 Recommendation

This report proposes that the Belectric battery storage unit be included within the EFCC project. It is the only option that is known to be capable of delivering the outcomes of rapid frequency response for the project, while mitigating the uncertainty of incurring further costs without risking delays to project timescales.

The Belectric battery will be the first based on flooded lead-acid technology (which is significantly cheaper than lithium-ion) will be used as a standalone frequency response unit in GB. This will give a comparison of investment cost, operational cost, lifetime and reliability between the two mentioned technologies. Furthermore, there is only one large-scale lead acid battery under construction on the island system of the Shetlands (1MW, 3MWh). This battery uses Valve Regulared Lead-Acid (VRLA) cells, limiting it to low C-rates (low power at a given installed capacity due to gel filled cells). VRLA batteries do not compare well with flooded lead acid batteries, since they deliver largely smaller C-rates than flooded batteries that minimises their effectiveness for providing rapid frequency response. Additionally they have a shorter lifespan (1500 cycles).

The combination of solar PV and battery storage within EFCC will generate learning on the benefit of linking technologies and how they can play a role in solving future network operability challenges. Any technical limitations will only be known if site trials to combine technologies are carried out. An important detail for Transmission Network Owners is the limited capacity of a battery has to be taken into account, whenever centralised control schemes and commercial models are developed. Currently the a number of international approaches concentrate on the pooling of units with limited capacity (e.g. battery, flywheels, etc...) and with unlimited capacity (e.g.gas turbines, coal fired power plants).

With the Belectric battery storage and solar PV solution, consumers will benefit from the full optimisation of EFCC outcomes from a realistic response portfolio of a wide range of service providers and industry acceptance based on realistic data. As highlighted in the EFFC Full Submission, this will enable the realisation of potential cost saving to consumers of approximately £200m per annum.

Appendix A Questionnaire sent to DNOs

On sending out an email enquiry to DNOs about their storage sites, a request was made to complete the questionnaire below.

- What Battery technologies were used in the individual projects (Li-Ion, NAS, Lead-Acid,…) ?

  - What ratio Capacity vs. Power is achieved?

  - Are these units able to also deliver reactive power i.e. voltage control?

- How is the battery operated - locally controlled, or distant control?

  - How fast is the communication in case of distant control? Is it deterministic?

  - What is measured in case of local control?

- By what scheme does is currently operate?

  - Frequency response?

  - Load shifting?

  - Emulation of rotating generators i.e. virtual inertia?

  - RoCoF control?

- What speed of response can they realize?

- What kind of inverters were used ?

  - What kind of control do they have implemented (current control or voltage control?)

- Are they black start capable?

- Are they containerized or require a dedicated building?

- Where are the units situated? e.g. isolated, in a substation,…?

  - Is there any storage system which is situated inside a PV power plant (and connected at the same point of interconnection?)

Appendix B Existing battery storage site evaluations

The table below shows the compiled data initiallty received in response to the questionnaire, from UK Power Networks, Northern Power Grid and Western Power Distribution for those sites eventually shortlisted.

Project Name	Smarter Network Storage Leighton Buzzard	CLNR Rise Carr/Darlington	Willenhall
Distribution Network Operator	UK Power Networks	Northern Power Grid	Western Power Distribution
Capacity	10MWh Capacity	500MWh Capacity	1MWh
Power	6 MW	2,5 MW	2 MW
Battery Technology	Lithium Ion	Lithium Ion	Lithium Ion
Reactive Power	Yes	Yes	Yes
Operated (Locally/Remote)	Remote	Local and Remote	Local and Remote
Type/speed of remote communications	Remote control yet to be fully tested	Fast response time is (under 100 milliseconds)	Fibre
Local control (measures)	Network configuration, voltage, loading, frequency amongst others	Voltage, current, reactive power	VT, primary substation demand and frequency control
Current Operation e.g Frequency Regulation, Primary Reserve, Peak Shaving, Voltage Regulation, Peak load Management	Static and dynamic frequency response, load shifting	Load shifting	Peak shaving, ancillary balancing services & arbitrage.
Emulation of rotating generators (synthetic inertia?)	No	No	Not yet confirmed
RoCoF control?	No	No	TBC
Speed of response	Designed to be <500ms	Response time of battery ramp output from 0-100% is 20ms	
Inverters used	6 x 1MW/1.25MVA Power Conversion Systems from S & C Electric	2 x 1.25 MW Bi-Directional AC/DC Power Converter Provided by 'Dynapower' Company LLC - USA	ABB 2MVA Inverter
Black Start Capable?	Yes but no scheme currently implemented in SNS project	Currently not configured for black start due to G59 requirements	Yes but prevented due to G59 protection
Location	Existing Substation	Existing Substation	Adjacent to substation
Relevant for EFCC?	YES	YES	YES
If not relevant for EFCC - why?	Not applicable	Not applicable	Not applicable
Containerized?	Bespoke Container	Bespoke Container	Bespoke Container
Integration into PV power plant	No	No	Neglible PV plant
Comments		on-site controllers support both Modbus TCP and DNP3 protocols for the control interface.	Due to commission end of July 2015. Frequency response available, but designed to have RoCoF / Vector Phase Shift protection installed as part of G59 installation.

Appendix B Existing battery storage site evaluations

The table below shows data for existing energy storage sites received from Western Power Distribution in response to theh questionnaire.

Project Name	Sola Bristol	FALCON	Solar Storage	Solar Storage	Isentropic Pumped Heat Energy Storage
Distribution Network Operator	Western Power Distribution	Western Power Distribution	Western Power Distribution	Western Power Distribution	Western Power Distribution
Capacity	12kWh Capacity split between 32 single phase units ~ 2kW capacity	5 x 100kWh Capacity	Min 300kVA	Min 300kVA	5.6MWh
Power	12kWh Capacity split between 32 single phase units ~ 2kW capacity	5 x 50kW	300kWh	300kWh	1.4MW for 4hours (75% efficiency)
Battery Technology	Lead Acid	Sodium Nickel Chloride	TBC	TBC	Thermal
Reactive Power	Yes	Yes	Yes	Yes	Yes
Operated (Locally/Remote)	Local and Remote	Local and Remote	Local and Remote control via operator	Local and Remote	Local and Remote
Type/speed of remote communications	GPRS communications	WiMAX point to point radio. Typical less than 200ms round trip	TBC (likely to be requested via operator manually)	TBC (probably UHF)	UHF
Local control (measures)	Solar PV output, AC property demand, DC property demand and voltage	Voltage, frequency & LV substation demand	TBC (likely to be voltage, real power, reactive power of the site which include PV output)	TBC (expect Voltage & PV output as a minimum)	Voltage & primary substation demand
Current Operation e.g Frequency Regulation, Primary Reserve, Peak Shaving, Voltage Regulation, Peak load Management	Domestic demand reduction & Network support	Peak Shaving, Frequency control, manually kVA output & Voltage control	TBC (expected to be Network Peak Shaving, generation output control and Voltage control as a minimum) Capable of ancillary balancing but outside of the trial scope.	Tbc (expected to be Network Peak Shaving, generation output control and Voltage control as a minimum)	Peak Shaving, Balancing Var flow. and arbitrage. Capable of ancillary balancing but outside of the trial scope.
Emulation of rotating generators (synthetic inertia?)	No	Not confirmed	TBC but probably not	TBC	Real inertia from rotating mass
RoCoF control?	No	No	TBC	TBC	Yes
Speed of response			TBC	TBC	TBC
Inverters used	Studer off grid inverters	Princeton Power Inverters	TBC	TBC	No inverters required
Black Start Capable?	Protection, Inverters are capable of off grid environments but currently not configured for black start due to G59 requirements	Protection, Inverters are capable of off grid environments but currently not configured for black start due to G59 requirements	TBC (probably not)	Tbc (probably not)	Has capability but G59 protection requirements prevent this
Location	Domestic Installation and Existing Substation	Existing Substation	On PV generation site	On PV generation site	Existing Substation
Relevant for EFCC?	No	No	No	No	No
If not relevant for EFCC - why?	Power/capacity too small	Power/capacity is too small also slow response due to Flow Battery type	Power/capacity too small	Power/capacity too small	Not battery storage and the response time of the system is far too high for the given project
Containerized?		No, custom installation at each site	TBC	TBC	Within a building
Integration into PV power plant	Yes	No	Yes	Yes	No
Comments	Vector Phase Shift protection installed as part of G59 installation	Vector Phase Shift protection installed as part of G59 installation	Project in procurement phase. Any frequency response TBC. However, RoCoF / Vector Phase Shift protection installed as part of G59 installation	Project in procurement phase. Any frequency response TBC. However, RoCoF / Vector Phase Shift protection installed as part of G59 installation	Frequency response available, but designed to have RoCoF / Vector Phase Shift protection installed as part of G59 installation. Real inertia provided by rotating mass

Appendix B Existing battery storage site evaluations

These tables show data for existing energy storage sites compiled from publically available information.

Project Name	CLNR High Northgate	CLNR Wooler Ramsey	CLNR Maltby	CLNR Wooler St Mary	CLNR Harrowgate Hill
Distribution Network Operator	Northern Power Grid	Northern Power Grid	Northern Power Grid	Northern Power Grid	Northern Power Grid
Capacity	200kWh Capacity	200kWh Capacity	100kWh Capacity	100kWh Capacity	100kWh Capacity
Power		100 kW	50 kW		
Battery Technology	Lithium Ion	Lithium Ion	Lithium Ion	Lithium Ion	Lithium Ion
Reactive Power					
Operated (Locally/Remote)	Remote	Remote	Remote	Remote	
Type/speed of remote communications					
Local control (measures)	N/A	N/A	N/A	N/A	
Current Operation e.g Frequency Regulation, Primary Reserve, Peak Shaving, Voltage Regulation, Peak load Management					
Emulation of rotating generators (synthetic inertia?)					
RoCoF control?					
Speed of response					
Inverters used					
Black Start Capable?					
Location	Existing Substation	Existing Substation	New Substation	Existing Substation	Existing Substation
Relevant for EFCC?	No	No	No	No	No
If not relevant for EFCC - why?	Power/capacity is too small	Power/capacity is too small	Power/capacity is too small	Power/capacity is too small	Power/capacity is too small
Containerized?	Bespoke Container	Bespoke Container	Bespoke Container	Bespoke Container	Bespoke Container
Integration into PV power plant					
Comments					

Appendix B Existing battery storage site evaluations

Project Name	Chalvey	Orkney Energy Storage Park	NINES Shetland	NINES Shetland	Nairn Flow Battery Trial	Hemsby
Distribution Network Operator	SSE	SSE	SSE	SSE	SSE	UK Power Networks
Capacity	25kWh Capacity (ave efficiency 80%)	500kWh Capacity	6MWh Capacity	3MWh Capacity	150kWh	200kWh Capacity
Power		2 MW	1 MW	1 MW	100kWp	200 kW
Battery Technology	Lithium Ion	Lithium Ion	Sodium Sulphur	Lead Acid	Zinc-Bromine Flow Battery	Lithium Ion
Reactive Power						
Operated (Locally/Remote)			Local and Remote	Local and Remote		
Type/speed of remote communications						
Local control (measures)						
Current Operation e.g Frequency Regulation, Primary Reserve, Peak Shaving, Voltage Regulation, Peak load Management						
Emulation of rotating generators (synthetic inertia?)						
RoCoF control?						
Speed of response						
Inverters used	Four quadrant power converter		DC/AC inverter	Three-phase DC/AC inverter		Between AC and DC bus
Black Start Capable?						
Location	Existing Substation	Existing Substation	Existing Substation	Existing Substation	Existing Substation	New Substation
Relevant for EFCC?	No	Yes	No	No	No	No
If not relevant for EFCC - why?	Power/capacity is too small	Not connected to the National Grid, so no use for the EFCC project	Decomissioned	Not connected to the National Grid, so no use for the EFCC project	Power/capacity is too small also slow response due to Flow Battery type	Power/capacity too small
Containerized?		ISO 40 foot container	Dedicated building	Dedicated building	Off the shelf container	Bespoke Container
Integration into PV power plant						
Comments						

Appendix C NPG Rise Carr 2.5MVA Battery Unit Detailed Costs

Shown below are detailed costs for the use of the Rise Carr site as provided by Northern Power Grid.

Commercially sensitive information

Appendix D Cost of Belectric Energy Buffer Unit (EBU) Battery Storage

Shown below are the detailed costs associated with the Belectric battery storage unit as provided in the EFCC Full Submission report in October 2014.

	Total Cost £K									
	Labour	**Equipment**	**Contractors**	**IT**	**IPR Costs**	**Travel & Expenses**	**Payments to users**	**Contigency**	**Decommissioning**	**Other**
Site preparation Y2			0	0	33.67	0	0	0	0	0
Install equipment Y2			0	0	72.39	0	0	0	0	0
Install equipment Y3			0	0	72.39	0	0	0	0	0
Establish and modify relevant IT systems Y2			0	0	32.71	0	0	0	0	0
Establish and test communication Y3			0	0	32.71	0	0	0	0	0
Establish and test communication - Equipment & IT Y2			0	572	0	4	0	0	0	0
Test and demonstrate response capability Y3			0	0	25.65	0	0	0	0	0
Test and demonstrate response capability Y4			0	0	51.31	0	0	0	0	0
Travel expenses - Y2			0	0	0	0	0	2	0	0
Travel expenses - Y3			0	0	0	0	0	4	0	0
Travel expenses - Y4			0	0	0	0	0	4	0	0
Contingency Y2			0	0	0	0	0	0	0	62
Contingency Y3			0	0	0	0	0	0	0	62
Contingency Y4			0	0	0	0	0	0	0	62
Category totals				572	320.82	4	0	10	0	186
TOTAL									**1092.82**	

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