Smarter Network Storage

Design and planning considerations for large-scale distribution-connected energy storage (SNS1.2)
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Introduction
1.1 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 transmission and distribution networks to benefit other industry segments, and a lack of scale demonstrations are currently hampering the efficient and economic uptake of storage by the electricity sector.

The Smarter Network Storage (SNS) project aims to carry 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 electrical storage projects by its demonstration of storage across multiple parts of the electricity system, outside the boundaries of the distribution network. By demonstrating this multi-purpose application of 6MW/10MWh of energy storage, the project will explore 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 and full economics of energy storage, helping to 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.

The energy storage facility is due to be deployed adjacent to a typical UK Power Networks 11kV primary substation in Leighton Buzzard where it is needed to support security of supply. Although such substation sites are typically classified as ‘operational land’ and therefore provide for some permitted development rights by licensed DNOs; in this instance full planning approval was required for the installation, as the adjacent land was and not historically used for operational purposes. This provided the opportunity to generate additional learning around the preparation and completion of the planning process which may be valuable to support increasing deployments of storage, either by DNOs, or by third-parties, where the need for planning consents is likely to be more common.

1.2 Report Scope and Objective

This report provides a summary of the key learning and considerations relating to the practical issues in the design and planning of large-scale distribution-connected electrical energy storage. It covers the learning generated from successfully securing planning consent to build an electrical energy storage device at the trial site, adjacent to the primary substation at Leighton Buzzard, and how this influenced the designs of the storage facility.

This report relates to battery storage using technology that is commercially available in 2013. A number of other storage technologies are available at different stages of maturity and all have advantages and disadvantages. The Department for Energy and Climate Change (DECC) has recently awarded funding which is seeking to achieve cost reductions and bring forward other promising technologies.

The report also provides an introduction to the planning consent process, which is required for most new structures and buildings, and is also required for the change of use of existing buildings or sites. The planning system for England and Wales is set out in the Town and Country Planning Act 1990 as amended by more recent legislation.

This document forms one of two main documents that together provide the evidence required to demonstrate completion of
the first formal Successful Delivery Reward Criteria (SDRC 9.1) milestone for the SNS project.

The SDRC is designed to show that successful early capture and dissemination of learning related to the practical issues in the design and planning of large-scale distribution-connected electrical energy storage has taken place, and this document forms the main learning report to be shared with stakeholders.

Other evidence for this SDRC comprises minutes and notes captured from meetings with the local planning authorities and environment agency, planning consents approval at the trial site, and design approval of the storage facility which are available to Ofgem on request.

The target audience for the report is other distribution network operators who may be looking to deploy further electrical energy storage capacity to support efficient distribution network operation; however the report will also have relevance for the following stakeholders:

- Third-party storage developers looking to develop and deploy storage for commercial operation, including selling flexibility services to DNOs;
- Local Authorities, who may increasingly need to understand the specific of energy storage technologies included in planning applications as the number of UK deployments increases; and
- Storage manufacturers and technology providers, to facilitate understanding of the main considerations and requirements in deploying their solutions within the UK network operator environment.
Design and Procurement Fundamentals
In the process of planning and design for distribution-connected storage to be owned and operated by a distribution network operator, the choice of site for storage is clearly a significant decision, and requires some very careful analysis in order to ensure storage is located appropriately. However, for distribution network scale storage, the choice of site is likely to be driven first and foremost by network need and so the primary application will typically be related to resolution of a network issue.

The first step to take, even prior to planning and design of any energy storage project, is to identify network issues or operational constraints that require intervention, and determine if energy storage could provide an effective solution as an alternative to conventional upgrades.

Once a network need is identified that can be potentially resolved by storage, the high level design for the storage will be affected by a number of drivers. These drivers will all have impacts on the final design choices, such as the nature of the storage technology, the type of supplier(s) approached and how it is deployed. In turn these impacts may have a reciprocal impact on some of the other key design choices and drivers. For example, the chosen technology, module size and method of housing may well impact both the cooling requirement and the noise level. They will certainly affect the foot print of the facility and together these will impact any local planning consents required.

This creates a wide range of interactions for the fundamental selection and design of distribution network scale energy storage. Figure 1 illustrates this interaction between drivers, design choices and impact.

The key findings from the design process that SNS has gone through are as follows:

The experience of SNS has demonstrated that converters are re-purposed from other renewable (e.g. wind farm) applications, this will limit the choice at which DC bus-bar voltage is set and is typically non-flexible for a particular manufacturer. In almost all designs, batteries were stacked vertically and connected in series, so that, in effect, the potential between the bottom of the battery stack at floor level and the top of the battery stack was equal to the DC bus-bar voltage. As such, the limited choice of DC bus-bar voltage determines the extent to which a facility can use height to mitigate land area. Height is limited in the reverse direction by planning limitations based on the visual impact to neighbouring buildings, and in the case of SNS, the need to raise the building out of a flood plain. Nevertheless, in a constrained foot-print, the choice of DC bus-bar voltage can be significant and Smarter Network Storage has seen a material impact of 7MWh or around 25%-30% between designs using different cell manufacturers and DC bus-bar voltages. On space constrained sites, the recommendation is to consider the DC bus-bar voltage which will maximise the available height. On rural sites where the building height determines the extent of visual impact, but land area is both cheaper and more readily available, then consider a DC bus-bar voltage that will minimise height.

The second constraint is the minimum quantum of storage and rating which the installation must have in event of a failure. This critically determines the number and rating of converters, since a space-efficient design with a single converter, if it were achievable, offers no redundancy. The number of converters and their separation dictates the space (within a constrained footprint) available for energy or MWh capacity.

The third constraint is fire suppression arrangements and maintenance requirements. The project has seen a circa 1MWh impact on a space-constrained site as a result of fire segmentation and lifting/handling requirements to maintain and replace battery racks. Whilst the second can be viewed as a trade-off with the down-time that is acceptable; i.e. a greater
packing density can be achieved at the expense of longer down-time and more complicated operations to replace battery failures, the first remains a necessity with current technology.

Figure 1 – Interaction of Storage Design Drivers and Key Design Choice/Impact
2.1 State of the Battery Storage Industry
It is important to start by clarifying both the elements that make up a battery storage facility at distribution scale, and the status of the supply chain. This is fundamental, since it determines the extent to which different and competing designs are available to choose from; and the extent to which any individual design can be tailored (or not) to a particular site.

The levels which make up a functioning battery storage system are shown below:

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<th>Level</th>
<th>Function</th>
<th>Comment</th>
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<tr>
<td>5.</td>
<td>Storage dispatch</td>
<td>This allows one or more ancillary service(s) (such as frequency response) to be provided from across a fleet of storage devices. It is unlikely to be implemented without also having an interface to market metrics and buy/sell prices.</td>
</tr>
<tr>
<td>4.</td>
<td>Scheduling</td>
<td>This allows a day or week’s worth of activities to be left to run on the storage device.</td>
</tr>
<tr>
<td>3.</td>
<td>Power converter functions</td>
<td>This implements ‘closed loop’ algorithmic control similar to a heating thermostat, allowing the system to respond and adjust to meet a set-point rather than simply charging or discharging blindly.</td>
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<tr>
<td>2.</td>
<td>Battery control system</td>
<td>This level is similar to the drivers on your PC, needing detailed knowledge of the hardware it is talking to.</td>
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<tr>
<td></td>
<td>Cooling control system</td>
<td></td>
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<td></td>
<td>Firmware</td>
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<tr>
<td>1.</td>
<td>Batteries</td>
<td>The physical hardware.</td>
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The SNS project incorporates all the various levels shown in the table above and does this through a supply chain consisting of S&C Electric, Samsung SDI and Younicos (levels 1, 2 and 3), AMT Sybex (level 4), and Kiwi Power/Smartest Energy (level 5).

The supply chain as it currently stands can be broadly characterised as follows:

**Battery Manufacturers:** Manufacturers of cell-level technologies, for example Samsung SDI, Dow Kokam and A123 Systems who are supplying batteries to Northern Power Grid's Customer Led Network Revolution project fall into this category.

**Power Conversion Manufacturers:** Manufacturers of inverter technologies. Both UK Power Networks partner on its Hemsby project (ABB) and the lead technology supplier on the SNS project (S&C Electric) fall into this category.

**System Integrators:** Agnostic of both AC/DC converter and battery technology, these system integrators are working across a variety of traditional substation, generation and renewable generation projects. They may either be major existing players in the power industry, for example: Siemens, ABB, GE, Alstom, or Mitsubishi. Alternatively, just emerging is evidence of a new type of system integrator concentrating solely on storage (for example, XtremePower, Zen Energy) and specialists in storage control software (Younicos and Greensmith).

The industry is widely accepted to be at an early stage, with new niches beginning to emerge, but yet to be proven as long-term pillars of the supply chain; and technology largely being re-purposed from other sectors.

This has two implications:

a) The two most fundamental components, the battery and the power converter, are likely to be inherited designs from other sectors.

b) DNOs and TNOs need to seek, and suppliers need to be willing to provide, information about financial stability throughout the entire supply chain.
3 Design Inputs
3.1 Site Selection for Storage - When can storage be used?
As described earlier, the starting point for any flexible intervention, such as storage, is to identify network issues or operational constraints that require intervention, and determine if energy storage could provide an effective solution as an alternative to conventional upgrades.

In developing the SNS project, a number of sites were therefore identified in an initial selection exercise that highlighted those requiring investment for some form of network upgrade due to capacity constraints. These capacity constraints can be a result of many different factors including generation levels, demand growth or even asset health.

In general, storage is most likely to be of greatest value for network upgrade deferral where several of the following statements apply:

a) The upgrade required is particularly costly, complex or time consuming to implement;
b) The upgrade required would add significant over-capacity that would remain un-utilised for a long period of time;
c) The main constraint driving the upgrade is relieved by a relatively small amount of additional capacity headroom; and/or
d) The main constraint driving the upgrade can be deferred by a reasonable amount of time (5+ years) and no other constraints are forecast to materialise which may trigger the upgrade.

A number of relatively simple criteria can therefore be applied to rapidly determine if storage is likely to be an effective solution for a particular site, prior to carrying out a more detailed assessment of the overall solution value.

Within UK Power Networks, all primary substation groups are categorised by a Load Index factor (LI) that is a measure of the site demand against the firm capacity (defined as the maximum capacity available during an N-1, or single-fault, event). These factors range from between LI 1 for sites with very little utilisation to LI 5 where there is a very high utilisation.

The criteria summarised in Figure 2 below were applied to sites with LI in excess of 3 in order to discount sites that were not likely to benefit from any intervention, or where the storage

Figure 2 – High-Level Criteria Applied for Initial Site Selection

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A. Determine substations that experience over-capacity of a certain duration
   > 100% forecast capacity factor as at 31 March 2015 for duration of >500MVAh

B. Filter out substations that experience significant over-capacity
   > 120% forecast capacity factor as at 31 March 2015

C. Filter out substations that have a high projected load growth rate
   > 2% forecast annual load growth rate from 2010/11 to 2014/15
solution value was not likely to be economical in deferring the upgrade; for example, sites with relatively high forecast demand growth rates. Further details on this process and the intermediate results were presented in Appendix G of the original funding submission for SNS.

Another main consideration in the case of the SNS project was the known availability of land at or near the potential site in which to locate the storage device. This was due to the requirement for a relatively rapid deployment of storage in order to carry out the trials within a reasonable timeframe as part of an LCN funded project. In practice however this may not necessarily be a primary consideration at the initial evaluation of network issues stage for other network-based or commercial deployments; as long as there were some suitable high-level options available for locating the energy storage device that could be explored.

For example, acquisition of new land or the purchase/lease and adaptation of existing housing facilities are still all viable solutions which can be factored in to a more detailed cost benefit assessment at a later stage, albeit with a likely increase to the typical timeline needed for deployment.

Having completed this assessment of network issues requiring intervention, and determining which were most likely to be efficiently resolved using storage, three primary substation sites were identified for further exploration by UK Power Networks:

a) Leighton Buzzard Primary, Bedfordshire
b) March Grid, Cambridgeshire
c) Shepway Primary, Kent

Leighton Buzzard site was identified and pursued as the preferred site for the SNS project, and is the focus of the remainder of this report.

3.2 Site Location - Leighton Buzzard Primary Substation

Leighton Buzzard emerged as the preferred site at which to build a storage device, and ultimately was the site where planning consent was granted, which is described later in this report.

This primary sub-station was in need of reinforcement within the next few years due to thermal capacity constraints of the two overhead lines feeding the site occurring at high peak-demand times. Peak demand at Leighton Buzzard has exceeded firm capacity limits between 9 and 37 days in each of the last five years (typically during periods of very cold weather). The limited additional capacity required has currently been provided by transfer capacity from neighbouring sections of the network, however peak demand at this location is forecast to continue to grow, and transfer capacity is limited at 2MVA. This means that limits may shortly be breached in future years and is the reason an upgrade is now required. The chart in Figure 3 below shows the demand profile across two particular high demand days in 2010, where site demand exceeded the firm capacity rating of the site.

The conventional reinforcement option to upgrade the site and mitigate this constraint was evaluated as a third 33kV circuit from the feeding site, Sundon Grid, to Leighton Buzzard primary substation, and a third 38MVA transformer located at Leighton Buzzard. This reinforcement would provide an additional 35.4MVA of firm capacity at Leighton Buzzard, which is significantly above predicted requirements for the medium-long term. The traditional reinforcement option, and alternative approach using storage, as described below, is shown in Figure 4.

The offset cost of this conventional reinforcement was also relatively high, again suggesting the site was a good match for storage and there was likely to be a meaningful contribution towards the business case necessary for distribution network scale storage.
Figure 3 – Load Profile for Two High Demand Days in 2010 at Leighton Buzzard Substation

Figure 4 – Leighton Buzzard Reinforcement Options
In this case, storage can be used as an alternative to building a new circuit and transformer by giving UK Power Networks the ability to reduce (net) peak demand take-off at Leighton Buzzard to maintain demand below the firm capacity rating. The reduction of peak demand could delay the need for this upgrade for a number of years. In addition, we are evaluating an up-rating option of the overhead lines which was identified in a parallel innovation project, which if achieved may further service the demand and delay or potentially avoid the need for traditional reinforcement altogether.

Although the storage device could theoretically be connected to the primary substation from a remote location, the site in this case also had more than sufficient land adjacent to it, on which to locate the storage device, as shown in Figure 5. In addition, there was further land available to accommodate a new transformer and switch house for future use when the storage device reached the end of its useful life and further new capacity was eventually required.

This site selection and identified potential location of the storage facility served to drive some fundamental design
choices due to a number of challenges associated with the land adjacent to the primary substation. Primarily these were the proximity to Clipstone Brook, a small stream close to the site, which meant some of this land was in a high-risk flood area as designated by the Environment Agency and the fact that the site was located relatively close to residential housing, as can be seen in Figure 5. This meant visual considerations were likely to be more important than if the storage was to be located at a remote, rural substation or one in an industrial area, for example. This has a financial consequence in terms of mitigation for both flood risk and appearance as such, SNS can be seen as a valuable stress test for the industry and the business case for storage.

3.3 Application Requirements
Having determined that energy storage may play a valuable role in solving a particular network issue at a suitable site, the next stage was to carry out further analysis to help define the technical application requirements for its resolution.

This process begins to identify some of the further key design considerations for the solution and is described further in this section. In the case of SNS, the level of site demand, technical details of the firm capacity constraint and expected demand growth were key in determining the appropriate rating of the energy storage system, as this was the primary or ‘anchor’ application in this instance.

3.3.1 Peak Shaving
As previously described, Leighton Buzzard substation comprises two 33/11kV 38MVA transformers fed by two 33kV overhead Lines (OHLs) from Sundon Grid, each with a winter rating of 35.4MVA that are currently the limiting factors to capacity available (‘firm capacity’) at the site in the event of a single fault (termed ‘N-1’). Licence conditions require UK Power Networks to provide a level of security of supply which is defined by Engineering Recommendation P 2/6. This sets out the minimum demand that needs to be met following the loss of one or more circuits at a site or “Group”. This requires a level of redundancy, appropriate to the group demand, such that in the event of one or more failures a certain proportion of group demand can still be met. At Leighton Buzzard only the “N-1” single failure situation requires consideration. The site firm capacity is currently restricted by the thermal rating of the 33kV OHLs and is therefore 35.4MVA.

At Leighton Buzzard, the P2/6 requirement is for the first 2/3rds of group demand to be met within 15 minutes, with the remaining total group demand to be met within 3 hours. This means that, in combination with the 2MVA transfer capacity described earlier, the allowable capacity in order to keep within P2/6 limits is 37.4MVA.

Although there is this limited transfer capacity available at site, it is desirable to avoid relying on reconfiguration of the network to achieve this. Ideally, this therefore means that the storage facility must, at a minimum, be capable of maintaining peak demands below 35.4MVA.

Note it has been assumed that with a battery energy storage device installed, improved power factor can be achieved through the independent provision of reactive power from the invertors. Therefore, whilst for network planning purposes MVA is typically used, it was assumed that these requirements broadly translate to MW (and MWh) requirements for battery
energy storage systems. This is because power factor will be closer to unity, and also as the margin of safety built into network designs and capacity thresholds will typically be larger than any adjustment.

Unlike conventional network assets and design philosophies, which typically consider power capacity only, both the power and energy need to be considered for storage. In order to assess the minimum requirements for the storage at Leighton Buzzard, an assessment of the daily demand profile was carried out to estimate the highest power and energy demand that would be required to be injected to keep overall site demand within the firm capacity limits. This is illustrated further in Figure 6, which shows the demand profile (in purple) for 20 December 2010; on which the greatest energy and peak power would be required (green shaded area under the curve) if this was supplied by the storage to keep demands below firm capacity limits (the red line).

Figure 6 – Illustration of Peak Power and Energy Requirements

| MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfirm | MVAh overfo
In this case, the maximum peak power output of the storage needed is approximately 40 MVA (the maximum height of the demand level above the threshold), and the energy capacity required is approximately 12MVAh. This essentially provided the minimum suitable bounds of power and energy for the storage device to be an effective solution for peak shaving and removing the constraint at the site in 2010.

To determine the upper bounds, the impact of additional demand growth and future constraints was considered in combination with the desired period for deferral of the network upgrade. The inherent uncertainty in demand growth at individual locations, and the impact of low-carbon technology adoption on demand patterns make this particularly challenging.

### 3.3.2 Future Expansion - Estimated Load Growth

The graph in Figure 7 shows the latest longer term view of winter peak demand at Leighton Buzzard, including local connection growth estimates.

Figure 7 – Winter Peak Demand Trend at Leighton Buzzard Primary
From these estimates, it can be seen that, due to a number of economic factors, the overall trend in demand growth has been a reduction in overall maximum demand since 2009. This suggests that the minimum power and energy bounds of 4 MVA /12 MVAh required from the 2010 profile in Figure 6 would in fact already provide some future-proofing. However, demand growth is expected to return as the economic environment improves, and so it was deemed important to provide further future-proofing of the solution.

It should be noted that the local load growth estimates also showed that, without intervention, demand is expected to exceed the site capacity limit around 2016/17, and therefore there was a requirement that any solution should be capable of being deployed within this timeframe.

Determining an appropriate energy capacity to cater for future growth is challenging because of the uncertainty in the way that the shape of demand will change in the future. If, as expected, electric vehicles become more commonplace, then this is likely to result in ‘peakier’ demand profiles and the need for a higher peak power rating for energy storage to mitigate resulting constraints. Alternatively, if consumption increases relatively proportionately across the daily profile, it is likely to be energy capacity that becomes the limiting factor.

It is therefore desirable to build in some allowance for growth in both these dimensions to provide the greatest optionality.

Naturally, providing for greater power and/or energy capacity has an impact on the cost and footprint of any storage solution, and so the allowance for maximum possible future expansion must be balanced with the overall solution value and cost-benefit compared to the traditional upgrade. In addition, many of the current ancillary services are capacity based, which means the value, and therefore the additional benefits achievable is proportional to MW rather than MWh, assuming a minimum level of energy duration can be achieved. The choice of maximum real and reactive power and energy is therefore also an important factor in the overall business case for multi-purpose use storage.

It became evident during the procurement process that, in the case of battery energy storage, the cost was most sensitive to increases in energy storage capacity, rather than the MW capacity rating, reflecting the fact that the cost of the battery units is typically a greater proportion of the total cost than the inverter units.

Following this analysis although based on earlier published planning date, it was therefore determined that an appropriate initial storage rating was 6MW/10MWh. This provided for an optimum amount of energy duration to initially meet current and some future peak demand at site, depending on the level of future load growth, while also providing for a peak power greater than strictly needed for the network constraint in order to maximise additional value streams.

It should be noted that with many energy storage technologies, it is possible to add further power and energy capacity throughout its operational life, therefore capacity for future expansion need not be installed on day one. In the case of battery energy storage this is possible through the connection of additional inverters and battery racks.

At the early design stage, it was therefore decided to design the building to accommodate further future expansion of both power and energy to provide greater optionality in the face of uncertain load growth and profile shape. Based on an assessment of potential maximum energy and power limits required to provide a significant period of deferral (10+ years), and using indicative estimates provided by manufacturers, the building was initially designed to accommodate future expansion up to 8MW/24MWh, as illustrated in Appendix 3.
(Following a subsequent necessary change of battery cell supplier, during further detailed design it became evident that it was no longer possible to accommodate up to 24MWh, which led to a revised layout design as described later in this report.)

**3.3.3 Secondary Applications**

In the case of SNS, as described in Section 3.3.1, the thermal capacity of the overhead lines was the constraint triggering the need for reinforcement at Leighton Buzzard and shortly followed by the thermal limit of the transformers being reached.

However, there is also a desire to maximise the value of the storage capacity, and determine if additional applications could help to improve the business case for storage. In addition, the storage is to be used as the means to explore a range of innovative commercial arrangements for the ownership and operation of the storage device. As such, the project was interested in exploring the use of any type of storage technology of sufficient technological readiness to be safely and effectively deployed at distribution-network scale.

These additional application requirements were specified in the technology tender in the form of ancillary services that were desirable for the storage solution to be capable of performing and included:

- Short-Term Operating Reserve (STOR)
- Dynamic and Non-Dynamic Fast Frequency Response (FFR)
- Power Factor Correction – through the provision of reactive power

These additional services place additional design considerations on the storage solution in terms of the capabilities and response times including:

- Ability to provide reactive power (VArs) (to provide power factor correction)
- Ability to provide power output response within 2 seconds (as required by FFR service)

- Ability to deliver at least 3MW output for at least 2 hours duration (6MWh) (as required by STOR service)

These application requirements, in conjunction with the determined storage ratings as described in Section 3.3.2, were used to guide the procurement process and therefore were additional key drivers in the resulting storage technology selection and design.

**3.4 Safety**

Safety is a primary consideration for all network technologies and interventions by DNOs, and so also impacted the selection of storage technologies during the procurement process and final designs of the facility.

There was a wide range of technology proposals that were received during the tender process, which is described further in Section 4.1; each of which have different characteristics and safety considerations as summarised on the following page:
## Storage Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Characteristics/Safety Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanadium Redox Flow</td>
<td>A rechargeable flow battery that uses vanadium ions in different oxidation states to store chemical potential energy. The electrolytes contain sulphuric acid, which is stored in external tanks. This presents safety and environmental concerns, especially if leakage to a water course is possible.</td>
</tr>
<tr>
<td>Lead Acid</td>
<td>These use lead plates in an electrolyte of sulphuric acid. They have a relatively good efficiency and are low cost. The lead and sulphuric acid are toxic and so present safety and environmental concerns for both normal operation and in the event of leakage.</td>
</tr>
<tr>
<td>Sodium-nickel-chloride (NaNiCl2)</td>
<td>This is a molten salt battery with good thermal cycling properties, but there are some thermal management safety concerns.</td>
</tr>
<tr>
<td>Lithium Ion</td>
<td>Typically solid or polymer-based electrolyte that results in limited risk of spillage or leakage. Lithium is flammable, resulting in relatively high fire risk in the event of overcharge or catastrophic failure conditions.</td>
</tr>
<tr>
<td>Sodium Sulphur (NaS)</td>
<td>This is also a type of molten-salt battery (constructed from liquid sodium and sulphur) with a high energy density, high efficiency of charge/discharge and long cycle lifetime. However there have been some recent safety management concerns because of the corrosive nature of the components.</td>
</tr>
<tr>
<td>Lithium iron phosphate (LiFePO4)</td>
<td>This variation of a Lithium-Ion battery has a lower energy density than the more common design used in consumer electronics. Because of its low cost, non-toxicity, the high abundance of iron and its excellent thermal stability it has gained market and safety acceptance, but limited deployments at large scale.</td>
</tr>
<tr>
<td>Liquid Air</td>
<td>Cryogenic based system operating at low temperatures and high pressure. Non-hazardous and non-toxic electrolyte materials, although lower energy density than some technologies results in a large footprint.</td>
</tr>
</tbody>
</table>
The specific site location was also a driver in terms of safety considerations because of the proximity to the watercourse and residential buildings, and due to the site being in a high-risk flood area. This would have specific implications for safety hazards connected with the proposed technology, in relation to its construction and impacts concerning its operation and so for UK Power Networks this guided the technology selection away from those solutions based on liquid electrolytes, or where there was some (albeit small) risk of hazardous liquids being released.

Naturally, the safety of employees and the public will be of primary concern in all distribution-connected storage deployments. However the risk appetite for certain technologies will depend on the individual organisation and may be higher for installations in remote or highly isolated locations where the consequences of catastrophic failure may be significantly lower.

3.5 Budget

Budget is likely to play a key part in determining some key design choices, including supplier selection and technology type. For storage to be a viable alternative there must be a robust business case that provides for a lower cost alternative, or additional benefits over the conventional upgrade.

While it is typically not economical to deploy storage in isolation (i.e. for investment deferral alone) for a distribution network operator, it is one of the main aims of SNS to generate learning relating to the wider business case for the multi-purpose application of storage. This includes how the provision of ancillary services may contribute towards the overall business case for storage and determine whether these additional benefits, in conjunction with investment deferral, provide for a viable lower cost alternative.

It is hoped that this learning will help to support other distribution network operators in the economic analysis of storage deployments to determine if it is likely to be a viable alternative. As part of the SNS project, an Investment Model Template has already been developed as part of a consultation relating to the potential business models for storage, which provides a tool for assessing the business case for a storage installation when it is deployed for a range of system-wide services under two different business models.

An understanding of the business case for storage, and the possible ranges of additional value that may be achieved, will help network operators, and/or third-parties deploying storage, to determine the upper bounds for the budget that can be tolerated for storage to be an economic alternative at a particular site for the resolution of a particular network issue.

It is out of the scope of this report to evaluate the full business case for the installation at Leighton Buzzard, as further learning is yet to be generated relating to the real benefits that can be achieved from operation on the networks and in the ancillary markets. For further information on the original assessment of the business case, the SNS funding submission analysed the estimated potential business case of the installation at this trial site and demonstrated that with ancillary value streams, once proven successful, it was possible for the deployment to provide benefits for customers.

For business-as-usual deployments, it is therefore expected that this evaluation would be carried out following site identification to determine whether storage should be used to meet the network need, and before proceeding with further storage design.

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4

Initial Design Outputs
4.1 Technology and Supplier Selection

At the stage of technology selection a preferred site at Leighton Buzzard, albeit requiring planning permission, had been identified as previously described. Although the eventual installation site might have had to alter, depending on the planning consent outcome, it was nevertheless helpful to have such a reference site and location to use when putting together the tender.

The capacity requirement of the device had been assessed, as described in Section 3.3.2. In order to assess potential for improvements in the future commercial operation of the device, variations for alternative configurations for increasing the rated capacity were also sought from suppliers. Where alternatives were proposed, explanation of the implications of the varying cost structures were requested so that a cost/benefit analysis could be undertaken.

The storage device manufacturer would design, manufacture, works test, supply, deliver to site, supervise the erection and installation, test and cold commission the system. Further testing would be required to demonstrate that the complete installation will operate safely and not have any detrimental impact on connected customers. A range of further appropriate tests from international standards would be required and agreed with UK Power Networks. These would include power frequency tests as well as lightning impulse tests and the installation would need to conform to the Distribution and Grid Code requirements.

A tender was prepared and issued in April 2012, for responses six weeks later. Responses were received from 15 suppliers offering between them 23 different solutions. All but one of the proposals were based on a form of electrochemical battery. The majority, 11 of the 15 suppliers offered their own manufactured battery solution, whereas the four non-manufacturers who essentially bought in the battery technology hardware were able to offer a much greater number of potential solutions and were essentially system integrators who were neutral about the choice of battery technology. The technology offered ranged right across the electro-chemical batteries spectrum from technically and commercially mature lead-acid batteries through nickel cadmium to advanced lithium-ion. The solutions offered were evaluated against seven criteria with four suppliers making the short-list. This was later reduced down to two preferred suppliers based on the technology.

The technology solution that rated highest was lithium-ion, in part due to the safety features proposed. This appeared to have key benefits when compared against the alternative technologies, and using the project’s design inputs described earlier. Of the two preferred suppliers, the key benefits that these proposals contained were:

- Proven technology with suitable reference sites and safety record, using technology that had no possibility of polluting flood or river course water;
- Physical size, weight and foot print area aligned with identified site location;
- Quick ramp-up response time of solution, allowing for wide range of applications;
- Ability to be housed in a variety of structures, including building aligned with site location requirements;
- Ability to be raised above the ground on stilts, to mitigate flooding risks; and
- Value for money.

There was little difference between the two preferred suppliers in terms of both the technology and the price offered. One was a battery cell manufacturer, who was proposing to appoint an established power systems company subcontractor as their second tier supplier to integrate the system and provide the necessary power electronics. The other was a power electronics systems company who would subcontract out the battery cell
manufacture to a subsidiary of a major chemical company able to provide the necessary battery cells. These categorisations are described earlier in Section 2.1.

Following further commercial discussions, the lead supplier S&C Electric Europe was appointed. S&C Electric then formally appointed second-tier suppliers of Samsung S&I (for the battery cells) and Younicos (for the control system aspects).

While the choice of technology may ultimately drive the type of main supplier selected, it was noted in the first SNS progress report\(^1\) that the supply chain for energy storage systems, and battery storage in particular, has been found to be relatively immature. A complex supply chain of second-tier suppliers is required for a fully integrated storage system, covering, for example, power-conversion equipment, battery cells and assemblies, advanced control systems, fire-suppression and cooling systems. Currently there are examples of players with a history in each of these areas who are targeting the market for fully-integrated systems, and all have the potential to be lead suppliers. It is not yet clear however which segment of the supply chain will eventually dominate in the supply of integrated systems, so it is likely there will be further shake-ups and consolidation in the coming years.

Based on the experience of this procurement exercise, there would appear to be merit in selecting a supplier who can provide a fully integrated solution, with some maturity as primary lead supplier. When the supplier S&C Europe was appointed, their original battery cell second tier provider fell out of the running through their own parent company’s choice. S&C however were able to find and select a replacement second tier battery cell supplier, which had not been identified at the start of the original procurement process. Therefore this time, it was possible to continue with the primary supplier chosen. The lack of financial strength of suppliers in this market has been evident and therefore significant effort should be placed on conducting financial due diligence.

This creates procurement challenges for energy storage systems and it was found that procurement databases, such as Achilles, do not necessarily capture the best or latest view of the potential supplier landscape. To overcome this, it is suggested that alongside existing procurement approaches, further market research is carried out to identify and capture additional emerging players, as was carried out in the bid-phase of the SNS project.

### 4.2 Module Size

Modularity of different energy storage technologies varies, but another key advantage of battery energy storage technologies, such as Lithium-Ion, is the flexibility in sizing and configuration.

Different manufacturers have different specific common inverter or battery module sizes that provide for certain configurations that are more cost effective than others. In the case of the selected technology supplier, inverter units of 1MW (1.25MVA) were available that could be combined to provide modular 2MW (2.5MVA) inverter units. This meant overall solutions of 2MW increments were optimal, and helped to determine the optimal design of the future expansion of up to 8MW power rating.

For the SNS solution, initially three sets of 2MW inverter units will provide the 6MW power output. Independent connection of these 2MW units provides for the ability to take units out of service and still have power and energy available.

Similarly, battery energy capacity can be added incrementally to each inverter, although it is desirable to have an even battery capacity across each main inverter unit to facilitate the even balancing of state of charge across the full system. The smallest modular unit from Samsung is defined as a ‘tray’ and consists of

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16 individual battery cells, providing for a nominal energy capacity of around 3.5 kWh per tray. For the SNS installation, 132 racks, comprising 24 trays each are then distributed across the inverter units to provide the total energy capacity for the installation (including approximately 1MWh nominal additional capacity to allow for natural degradation).

4.3 Storage Housing
Several large-scale battery energy storage providers offer standardised solutions based on batteries installed in ISO shipping containers.

At the identified site, the electrical energy storage facility is to be located in close proximity to public rights of way and residential housing, so it was determined at an early stage that a containerised solution was unlikely to be acceptable to the community, and also therefore to the Local Planning Authority, and so a building-housed solution would be necessary.

Due to the flood risk at site, it was also deemed necessary to specify that the storage building must be raised off the ground to allow any flood waters to flow freely underneath so as not to increase flood risk through displacing water, or itself be at risk of flooding.

In order to ameliorate the visual impact of the proposed development, the overriding consideration was to minimise, as far as possible, the size and volume of the building. The second design consideration was to design any facade of the building such that it minimised the apparent bulk of the building when seen from key viewpoints.

Finally, it was deemed necessary to provide some form of effective landscape screening to the resulting development, including the security fence around the new substation compound.

4.3.1 Storage Housing - Design Criteria
There were a number of design criteria that needed to be followed, based on UK Power Networks requirements and those anticipated to be important for securing planning consents. A range of surveys and studies at the Leighton Buzzard site, were conducted in line with UK Power Networks civil standards help to define a range of initial design criteria.

The following resulting considerations were therefore important design factors:

- Keeping the volume and height of the proposed substation structure(s) to a minimum so as to keep the visual impact of the facility to a minimum;
- Keeping the cost of construction to a minimum;
- Use of good quality facing materials that will result in the minimum of maintenance being required and extending the life of the facility;
- Facing materials that will help the building blend in with the surrounding area;
- Use of landscaping to ameliorate any negative visual impact; and
- Existing 33kV underground cables on site, so no buildings should be located over these cables.

In order to mitigate flood risk, the following factors were required in the design:

- No raising of the site ground level;
- A clear void under the building to allow for flood water to pass freely and occasional access for maintenance purposes;
- No amendments should be made to the cross-sectional alignment of the bank of Clipstone Brook;
- No tree-planting close to the watercourse edge;
- No bunding of any kind is included in the design to prevent displacement of potential flood waters; and
- An easement between the perimeter fence, along level ground, to the edge of the watercourse to allow access for maintenance.
For visual amelioration purposes, it was proposed to introduce landscaping along three of the four boundaries: along Woodman Close, along the boundary facing the river bank, and along the boundary parallel with the existing substation boundary (northeastern boundary).

Other considerations, relating to security and environmental impacts included:

- Within the secure compound, any electrical plant should be kept at least 2m away from the security fence in accordance with UK Power Networks civil engineering design standards;
- To safeguard an area for wildlife, it was advised that any new development should be kept from between 5m to 8m from the top of the river bank;
- An area of open land within the secure compound is required for circulation and temporary storage of surface water run off; and
- No trees should be planted closer than 2m from the demarcation fence in case they are used as climbing aids.

Some of the resultant architectural features of the substation building reflect the function of the building, namely:

- There are no windows to the building;
- High security doors to the building;
- A 3m-high security ‘Weldmesh’ fence around the perimeter of the compound for security; and
- A 1.2m-high secondary ‘demarcation fence’, with a 2m clearance between it and the ‘Weldmesh’ fence, with shingle on the compound area.
5

The Planning Process
5.1 Planning Permission

Obtaining planning consent is the process required in the UK in order to be allowed to build on land, or change the use of land or buildings. Within the UK, the occupier of any land or building will need title to that land or building i.e. “ownership”, but will also need “planning title” or planning permission. Planning title was granted for all pre-existing uses and buildings by the Town and Country Planning Act 1947, which came into effect on 1 July 1948. Since that date any new development has required planning permission. The planning system for England and Wales is set in the Town and Country Planning Act 1990 as amended.

Development as defined by law consists of any building, engineering or mining operation, or the making of a material change of use in any land or building. Certain types of operation such as routine maintenance of an existing building are specifically excluded from the definition of development. Specified categories of minor or insignificant development are granted an automatic planning permission by law, and therefore do not require any application for planning permission. These categories are referred to as permitted development. Electricity undertakings, such as licensed distribution operators are also permitted to make developments on their own property under a General Development Order, under the Electricity Act 1988. Some other developments, such as power stations and overhead lines require consents under the Electricity Act and not the Town and Country Planning Act.

In the case of any proposal there is therefore a two stage test: is the proposal defined as development and, if the proposal is development, “is it permitted development?” Only if a development is not “permitted development” would an application for planning permission be required. An application for planning permission should then be made to the Local Planning Authority (LPA).

LPAs are generally the local borough or district council, although an application for a mining operation, minerals extraction, or a waste management facility would be decided by the local county council in non-metropolitan areas. Within a national park planning applications are submitted to the national park authority.

In the case of SNS, the LPA for the Leighton Buzzard site was Central Bedfordshire Council.

All LPAs have their own websites which provide access to relevant application forms, contact details and other relevant documents. LPAs are generally receptive to pre-application discussion in order to clarify whether a proposal will require planning permission and, assuming that it does, the probability of such planning permission being granted. These pre application discussions are often called “place-maker” meetings.

5.2 Determination

The law requires that all applications for planning permission should be decided in accordance with the policies of the “development plan,” unless material planning considerations indicate otherwise. The decision on any planning application is therefore “policy-led” rather than “influence-led”. Although the public and nearby residents will be consulted about almost any planning application, the decision will not be made on the grounds of popularity or unpopularity. The framing of the decision by reference to published planning policy prevents the decision on a planning application being made on grounds which are perverse and arbitrary.

It is therefore most important that applicants for planning permission satisfy themselves about the relevant local development plan policies before making an application. These can also be viewed via the LPA’s website, or the UK Government’s Planning Portal, which provides a nationwide clearing house on planning information and advice for both Government and local planning policies. As a practical matter it is advisable to discuss
proposals with the LPA before incurring the fees and other costs that are involved in making a planning application, or the delays and abortive costs that would arise from the refusal of planning permission.

5.3 Type of Application
A number of different types of planning permission can be applied for:

5.3.1 Full Planning Permission
Full planning permission would grant permission for all aspects of the proposed development, although it would generally be subject to various conditions (see below).

5.3.2 Outline Planning Permission
This cannot be granted for a proposed change in the use of land or buildings. It might be appropriate when an applicant is seeking an agreement “in principle” to a proposed development, without being committed to a particular form of design or layout.

5.3.3 Approval of “Reserved Matters”
Seeking permission for those aspects that were not dealt with in an outline planning permission or seeking approval of aspects of a development which were reserved by a planning condition in an earlier grant of full planning permission.

5.3.4 Renewal of Planning Permission
This would arise when an earlier outline or full planning permission was subject to a time-limiting condition which has since expired. In essence this requires the entire planning application to be reviewed in light of current rather than previous planning policies. Applications for renewal of an earlier planning permission are usually granted anew, unless there has been a significant change in the relevant material considerations which are to be weighed in the decision.

5.3.5 Removal or Alteration of a Planning Condition
as a matter of law, conditions should only be imposed on a grant of planning permission when compliance with that condition is essential to make an unacceptable development acceptable, so it would be refused planning permission were it not for that condition. If the applicant or developer wished to proceed with a development without compliance with a condition, or perhaps with the condition in an alternative form, then an application can be made to “vary” the condition concerned, possibly by deleting it or offering an alternative form of words. Note that the LPA cannot alter any planning condition which imposes a time limit when the development is to be commenced. That would require a re-application for full or outline planning permission, but since October 2009 it has been possible to apply to extend an existing consent.

5.4 Timescales
Each type of application has a timescale for when a decision has to be made. These are set by the Government and can range from between four weeks and 16 weeks. Councils are permitted to agree with the developers for an extension of time, providing both parties can agree, although the precise mechanism appears to differ depending on the LPA. If the Council fails to make a decision within the necessary timeframe or the agreed time extension, the applicant can appeal to the Secretary of State for non-determination of an application. Full planning or outline planning applications must ordinarily be determined within eight weeks of its submission unless it is deemed to be a major application. This time can increase to 16 weeks if the application includes an environmental statement, although as was the experience within the SNS project there is the potential for these timelines to be extended. The time scale for a change of use application is eight weeks.

5.5 Planning Classifications
Uses of land and buildings are classified into “use classes” and
any change from one use class to another use class is automatically a “material change of use” amounting to development. Some small scale changes between use classes are nevertheless “permitted development” and hence do not require planning permission. Certain types of use or activity do not fall into a specific use class and are termed “sui generis”.

“Sui generis” was the classification deemed most appropriate for the application at the Leighton Buzzard trial site as, similar to the nature of the current electricity regulatory frameworks, the classification of energy storage is not explicitly or clearly covered. For example, there is a planning permission use class entitled ‘Storage or Distribution’

http://www.planningportal.gov.uk/permission/commonprojects/changeofuse/1, however this typically covers the physical storage of equipment or materials, such as oil drums, tyres or logistics/distribution centres and may therefore carry some negative connotations with local stakeholders which would not necessarily be representative of typical energy storage deployments.

It is not clear if all LPA’s would categorise an electrical storage device development by a non-DNO or electricity utility company as requiring “sui generis” use and there appears to be some leeway in their assessment. Any change of use of “sui generis” land requires planning permission. In practice most uses are a composite of several uses so that, say, a factory might well have an ancillary office and perhaps storage uses, all within the same premises. In such a case however, the primary use would be that of a factory (use class B1 or B2).

5.6 Conditions
Planning permission is usually granted subject to a planning condition which requires the development to be commenced within three years. Typically they will also include a number of other conditions, for example the scheme to be built in accordance with the approved drawings, trees to be planted as per the landscape scheme and replaced if they die in the first few years, or the colour and finish of external materials to be approved by the local authority. Some of these will need to be complied with before any work starts on site; others will take effect once the development is commenced, or later.

Most conditions imposed on a granted planning permission will relate to implementation of works within the actual site of the application (the edges of which must be defined by a red line marked on an accurately scaled map of the site, usually an Ordnance Survey extract, accompanying the application). If there is a need to control aspects of the development which are required to occur outside the defined application site such as related highway improvements, then the implementation of those aspects can be required by a ‘Grampian condition’. This would be worded to the effect that the development being permitted must not be commenced (or must not be occupied, as appropriate), until the required off-site works had been completed.

5.7 Section 106 Agreements
Planning conditions are imposed to require that something is done or not done by the developer in order to make the development acceptable. Sometimes, planning permission will only be granted subject to the applicant entering into a legal agreement under Section 106 of the Town and Country Planning Act requiring that certain things be done or money be paid to the local planning authority e.g. to contribute towards the improvement of a highway junction serving the development before the development commences. Such contributions can only be required if they are necessary to make the development acceptable and relate directly to the development proposed.

5.8 Development Control
Development control or planning control is the system of town and country planning through which local government regulates land use and new building. It relies on a “plan-led system” whereby development plans are formed and the public is consulted. Subsequent development requires planning permission, which
is granted or refused with reference to the development plan as a material consideration. If the local plan had designated the proposed development site as land for something other than utility services, as was the case at Leighton Buzzard, then in spite of the fact that UK Power Networks owned the land and had always held it for future operational use, this alternative designation in the local plan could dissuade the planning officers from granting approval. To counteract this it is useful to monitor and comment on local plans at each publication.

5.9 Nationally Significant Infrastructure
The Planning Act 2008 introduced a new planning system for nationally significant infrastructure projects. The Government is producing a series of twelve National Policy Statements that will explain its policy on each type of infrastructure project. A number of National Policy Statements have been introduced, covering major energy projects (oil, gas, coal, nuclear power and renewable energy from things like wind farms), ports, and sewage treatment.

Developers wanting to apply for consent for a project must first consult local communities and groups that may be affected by the project. Applications are generally dealt with by the Planning Inspectorate’s National Infrastructure Directorate, to a timetabled procedure.

Planning Inspectors take decisions on behalf of the Secretary of State. They apply the policies in the National Policy Statements when making decisions. They take into account any matter they consider important and relevant. This could include a draft National Policy Statement, where the final statement has not yet been adopted.

It is unlikely that the scale of most distribution-connected energy storage would fall into the category of nationally significant infrastructure, and is therefore not considered further in this report.
6

Obtaining Planning Consents
6.1 Planning Consents at Leighton Buzzard

Work to develop the planning application for the trial site at Leighton Buzzard began in May 2012 during the early project bid phase, when pre-application guidance was sought from Central Bedfordshire Council based on the initial designs of the exterior of the storage housing. The guidance provided at this place maker meeting offered the range of relevant policies that should be considered in the full application and also included initial comments from a range of key external stakeholders, such as the Environment Agency and local Highways Officer.

Planning consultants, Adrian Salt & Pang, were appointed by UK Power Networks to assist in this process, providing guidance in compiling the planning application. In order to maintain consistency they have remained the main interface with the council’s Planning Case Officer.

At an early stage, UK Power Networks agreed with its planning consultants that planning permission would be sought under the Town and County Planning Act as the proposed development was not covered under the scope of a general development order within the Electricity Act.

6.2 Alternative Locations Considered to Meet Sequential Tests

From this initial pre-application guidance, as engagement continued with the council it became clear there were outstanding concerns relating to the basic need for the development at the specific site and location identified. This was particularly due to flood risk at the site, and the fact that the land was reserved for green-space according to the council’s Local Plan Review Policy, despite it being under the ownership of UK Power Networks. It was therefore necessary to provide additional analysis into the financial and technical viability of alternative theoretical locations over and above that already provided. This assessment was crucial to ensure the ‘sequential test’ required by the National Planning Policy Framework was satisfied, which is designed to ensure that development is located in the most sustainable location first, before other, less sustainable locations are chosen.

Ideally the best technical solution was to locate the storage device immediately adjacent to the existing primary sub-station as described earlier. However, with the potential of flooding and the close proximity of residential housing it was necessary to consider potential alternatives, of which there were two. Either locating the storage device at a normal open point, within the primary network or alternatively finding a suitable satellite site at which to locate the storage and connecting it back to the primary by way of two separate 11kV circuits.

Six normal open points (NOPs) within the Leighton Buzzard Primary group were identified as being potentially suitable for connecting the storage device, these are shown in Figure 8. However, on further analysis none of them proved suitable. There was either too little land or space available, again due to the urban location of each and their proximity to housing, or the existing feeders through which a device would be connected would require significant upgrading or replacement. In one instance there were also security concerns relating to the location of the cables and routes back to the primary substation which would be at high risk of damage by any street works.
Figure 8 – Alternative Sites Considered

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>AREA</th>
<th>ISSUES</th>
<th>SEQUENTIAL TEST OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Flight Equipment Substation</td>
<td>Flood Zone 3</td>
<td>+ Flood risk; cables are outside substation, security concerns</td>
<td>FAIL</td>
</tr>
<tr>
<td>2. Pages Industrial Estate NOP</td>
<td>Industrial Estate</td>
<td>+ Exisiting cables require upgrading;</td>
<td></td>
</tr>
<tr>
<td>3. Harrow Park NOP</td>
<td>Housing Estate</td>
<td>+ Disruption to Highway;</td>
<td></td>
</tr>
<tr>
<td>4. Woodman Close Substation</td>
<td>Vacant Land in a Residential Area Flood Zone 3</td>
<td>+ EPN does not own additional land; insufficient land available</td>
<td>FAIL</td>
</tr>
<tr>
<td>5. Copthill Avenue NOP</td>
<td>Housing Estate</td>
<td>+ EPN does not own additional land;</td>
<td></td>
</tr>
<tr>
<td>6. Marry Fields NOP</td>
<td>Housing Estate</td>
<td>+ Insufficient land available</td>
<td></td>
</tr>
<tr>
<td>7. Liptons NOP</td>
<td>Industrial Estate</td>
<td>+ Existing cables require upgrading;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ Disruption to Highway;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ High financial outlay</td>
<td>FAIL</td>
</tr>
</tbody>
</table>

Key:
- **EASTERN NETWORK WOOLSEY CLOSE SITE**
- **POTENTIAL SITE – NORMAL OPEN POINT (NOP)**
An alternative satellite site existed at a location 2 km from the Leighton Buzzard primary on existing farm land, at a site east of Leighton Linslade that was designated for Industrial use. However, the land there had not been acquired by any potential developer nor was there any certainty that UK Power Networks could acquire anything suitable. No planning approval even in outline had been granted and the site would require two new 11kV circuits to be constructed, creating major disruption to the roads in the centre of Leighton Buzzard. This would quickly mitigate one of the key benefits of using storage as an alternative to conventional reinforcement: avoiding major disruption from the need for a third EHV circuit feeding Leighton Buzzard primary. The conclusion was that the most appropriate and feasible location to install storage was as initially identified, adjacent to the primary substation located in Woodman Close.

### 6.3 Pre-Application Local Consultation

In November 2012 and prior to the submission of a planning application, a local consultation exercise was carried out which involved distributing a leaflet to local residents and businesses. This leaflet was distributed to approximately 100 residents, local businesses and the local school in the immediate vicinity of the existing substation. The circulation list was advised by the Local Planning Authority, Central Bedfordshire Council. Three local councillors were also sent a copy of the leaflet. The consultation was required in order to seek views and feedback on the proposed development which could then be incorporated in the designs and planning application. The leaflet, which is given in Appendix 1, explained the need for the development, details of the design and the impact of the storage solution.

By the end of November 2012, 17 responses had been received and these highlighted a number of key areas of concern that were to be addressed where possible in the full planning application, as illustrated below. The general theme of the responses centred on the aesthetics of the proposed building and on safety. Two-thirds of the respondents wanted better screening of the proposed building with more and taller trees to hide the building as much as possible.

One third of responses asked questions relating to safety, in particular there was concern over any chemicals used in the storage device; regarding displaced water in the event of flooding, in the use of security lighting or in one case relating to electrical emissions.

Regarding the specific questions that were asked in the consultation more than half had suggestions relating to the use of the surplus land and there were a number of issues raised relating to a cycleway that Central Bedfordshire Council were keen on extending to run between the existing substation and new storage development, and the river, Clipstone Brook. In general residents wanted the land improved and better maintained, two specifically wanted allotments and one wanted it left natural for wildlife.

Four responses specifically did not want a cycle path along Clipstone Brook, which runs along the south eastern boundary of the site. The reasons ranged from the pathway which would be out of sight, encouraging various forms of antisocial behaviour, reducing the soak away during flooding, the effect on the wildlife and safety concerns in relation to speeding cyclists and small children who play in the area.

Four respondents either supported what has been proposed or did not object to the principle of the development. Two residents stated that they would be writing to Central Bedfordshire Council to object, three would like us to respond to them and two would like a local public meeting to discuss the matter. Two residents wanted to know what other sites UK Power Networks had specifically considered.

### 6.4 Consultation Responses

A summary of the responses to the Local Consultation leaflet
are shown below. These are grouped into different categories for ease of review and are also included in a pie chart shown in Figure 9 right.

6.4.1 The Site:
- Why do we need another substation in the area?
- Why does it have to be in a residential area and not near the developments it is being built to supply?
- Fencing should be repaired and vandal proof, so that people do not tip rubbish or use it as a “short cut” particularly if there is a cycle path. It should be high fencing.
- Mixed feelings about having a cycle path because of the children playing there.
- Which other sites were considered?

6.4.2 The Building:
- Could it be built in brick so it blended in with the housing?
- Could it either be coloured various shades of blue from dark to lighter from bottom to top to blend in with the skyline or green to blend in with the trees and shrubbery used to screen it?
- Could mature trees and shrubs be used to screen the building rather than waiting for new trees to grow? How high will the screening be?
- Will there be solar panels on the roof of the building?
- What will happen to the old building?
- Will the building be silent?

6.4.3 The Landscape and Waste Land:
- Will there be on-going maintenance of all the landscape?
- Could some of the waste land be used as allotments?

6.4.4 The Construction:
- How long is it going to take to build?
- Will there be noise and disruption while it is being built?

6.4.5 Health and Safety issues:
- What kind of cabling will be used to convert DC to AC and will it be underground?
- Are there any chemicals in the equipment being used which could cause a health risk if the area were to flood?
- Would there be a massive discharge of electricity if an accident occurred?
- Will there be more vehicles parking in Woodman Close?
- What planning has been done so that the existing housing is not affected by floods? Do you intend to increase the flood defences?
- Can you confirm there are no health risks living so close to a power station?
- What effect will the security lighting have on the housing and will there be any shading of it?

6.4.6 Property Values:
- House values will go down as a result of this. What compensation will be available?

6.4.7 Public Meeting:
- Would there be a public meeting?

6.5 Preparation and Submission of Planning Application
The planning application for Leighton Buzzard, incorporating a number of studies detailed below, was successfully completed and registered with Central Bedfordshire Council on 8 February 2013. Engagement continued with the Local Planning Authority, Central Bedfordshire Council and the Environment Agency throughout the application period.

A significant number of studies and analyses were completed during the period May 2012 – February 2013. These were managed by UK Power Networks’ Capital Programme team, who will be managing the site construction works. This ensured that a detailed design and access statement could be compiled for the full planning application. A summary of the various component studies and documentation that was required is illustrated in Figure 10 right.
Figure 9 – Summary Chart of Consultation Responses

<table>
<thead>
<tr>
<th>CONSULTATION RESPONSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Social impact (local)</td>
</tr>
<tr>
<td>5% Project Build (period)</td>
</tr>
<tr>
<td>16% Technology (safety)</td>
</tr>
<tr>
<td>9% Support/No concern (in principle)</td>
</tr>
<tr>
<td>45% Visual</td>
</tr>
</tbody>
</table>

Figure 10 – Supporting Studies and Design and Access Statement Structure

<table>
<thead>
<tr>
<th>Supporting Studies</th>
<th>Design and Access Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prelim Contamination Assessment Report</td>
<td>Rationale for Development - Analysis of Strategic Options</td>
</tr>
<tr>
<td>Local Consultation Exercise and Analysis</td>
<td>Design Criteria, site Layout and Design</td>
</tr>
<tr>
<td>Ecological Study</td>
<td>Landscaping Plans and Planting Specification</td>
</tr>
<tr>
<td>Archaeological Survey</td>
<td>Environmental Impact Assessment and Sustainability</td>
</tr>
<tr>
<td>Background Noise Study</td>
<td>Conformity with Strategic and Local Planning Policies</td>
</tr>
<tr>
<td></td>
<td>S106 Agreement - Heads of Terms</td>
</tr>
<tr>
<td>Geoenvironmental Assessment Report</td>
<td>Land Valuation</td>
</tr>
</tbody>
</table>
The initial date set for a decision was 5 April 2013. As this application was not considered to be a major application the decision date was based on the statutory planning timescales of eight weeks. However at the beginning of April the council requested that UK Power Networks withdraw and re-submit the application to allow them more time to conclude outstanding matters regarding the application. This included the terms of the s106 agreement which were not yet finalised, as described further below. Although strictly not necessary, as in theory, the council could have looked to mutually agree an extension, the application was successfully re-submitted and re-registered by the Council on 12 April 2013 and this gave Central Bedfordshire a further 8 weeks to conclude their enquiries.

6.6 Need for Community Infrastructure Obligations

The pre-application guidance highlighted early-on; the requirement to enter into a legally binding ‘section 106 agreement’ (s106) due to the scale of the development, as described in Section 5.7.

It was proposed this s106 should cover some suggested community infrastructure contributions, due to the loss of some of the green-space for the community, including use of the land owned by UK Power Networks which was not specifically to be covered within the application.

Negotiations relating to these financial contributions took significantly longer than expected which was in part due to feedback received during the local consultation which highlighted that a number of residents were not in favour of a cycleway. The provision of a cycleway, or funding towards it, was however highlighted as desirable during the initial pre-application guidance from the council but was not deemed appropriate or relevant to the development by UK Power Networks.

Following re-submission of the planning application after the initial statutory period had expired, a meeting was held with the Council on 8 April 2013 to discuss the terms further. At this session, the terms of the s106 agreement were fully agreed and full planning consents was later issued by the council on 7 June 2013, subject to a range of pre-commencement conditions and s106 terms.

A summary of the overall timeline for the planning process, including the main engagement points with the LPA and EA and the main studies completed is shown in Appendix 2.

6.7 Key Components of the Section 106 Agreement

The following provisions are contained within the Section 106 Agreement made with Central Bedfordshire Council:

1. Lease to Central Bedfordshire Council the remaining land not used in the development for recreational/leisure purposes of the local community. This lease is for 99 years with a break clause any time after 20 years.

2. Transfer a 5m width strip of land that runs along the bank of Clipstone Brook to Central Bedfordshire Council for their use in constructing a cycleway path, if and when they so choose.

3. UK Power Networks will during the next planting season following the physical completion of the development, plant extra tree screening round the existing substation in order to improve the visual aspects of the whole area.

4. UK Power Networks will reinstate fencing between the leased land in point 1 above and the road Woodman Close. It will also provide some new fencing across the corner of the existing sub-station site and South Street to aid the Council in building a cycleway entrance.

5. UK Power Networks will make a one off financial contribution towards the upkeep of the land leased to central Bedfordshire Council in point 1 above.
Design Impacts
This section describes the final designs of the storage facility, following public consultation and planning consents and incorporating the various design drivers described above and from the wide range of studies and assessments carried out at the local site.

7.1 Building Exterior Civil Design
The building comprises a mono-pitched single-storey building of approximately 40m x 20m in plan, based on key design advice received from the Council during the pre-application guidance stage.

These dimensions were specifically designed to allow for the storage device to expand in future, and based on further detailed layout design allow the capacity of the device to increase by 2MW and the storage capacity to extend up to 17MWh. This limitation is described further below in Section 7.4.

The highest point of the building is 8.3m above ground level, with the lowest point, where the building fronts Woodman Close, being 6.6m (this compares to 5.5m which is the height to eaves level of the houses on Woodman Close).

The local ground conditions and mass of the storage system require a piled foundation. Above ground the building structure will be a combination of steel beams and reinforced concrete.

The external appearance of the building was adjusted, having originally been proposed to be clad in shades of blue. Following feedback from local residents, the pattern of the cladding was adjusted and the colour is now in shades of green as shown in the following diagrams, Figure 11.

This gradation in colour, combined with the patterning, accords with, and reinforces, the dark colour of the proposed landscaping, set against the sky. The overall effect is to reduce the apparent bulk of the building.
Figure 11 – Proposed Visualisation and Elevations with Landscaping

NORTH-WEST ELEVATION - VIEW FROM WOODMAN CLOSE

SOUTH-EAST ELEVATION - VIEW FROM CLIPSTONE BROOK

NORTH-EAST ELEVATION

SOUTH-WEST ELEVATION
7.2 Flood Mitigation Design

The consultation with the Environment Agency during the planning process led to the design of the building raised on stilts to ensure that any potential flood waters were not displaced, increasing the risk of flooding elsewhere.

Based on the flood-risk assessment work carried out for the Environment Agency, the 100-year worst-case predicted flood levels were estimated at around 0.66m above the ground level of the development. In order to prevent any water displacement and increase in flood risk, it was therefore necessary to raise the building by at least this amount. However, health and safety policies within UK Power Networks would mean that any void under the building less than 2m would be classed as a confined space. In this case, additional measures must be employed when carrying out maintenance or other work to ensure safety of operational staff. It was therefore desirable if possible to ensure the void was not a confined space to ensure easier maintenance and access if needed. For this reason, the decision was taken to raise the building by 2m (at the lowest ground level point), which serves to provide for easier access and mitigates against the predicted 1000-year flooding event.

The under-floor void to the building will be enclosed on three sides with steel palisade security fencing but clad to ground level on the road frontage elevation. In this way the building will appear solid when seen from the road.

There was initially some concern from the Environment Agency regarding the potential for debris to become trapped in the palisade fencing which may impede the flow of waters under the building in the event of a flood. However, this was ultimately resolved through bilateral discussions and amendments to the fencing design which included wider gaps between pales and an increased gap between the ground and bottom of the fencing.

In addition, as part of the planning conditions associated with consent, a flood maintenance plan has been put in place that ensures a process is mapped out for the clearance and removal of any debris following flood events. The design also incorporates a flood alarm to be installed at site, which alerts UK Power Networks control engineers in the event of a flood at site.

This raised building design also needed to be balanced with the need to minimise the visual impact of the building and keep it below the levels of existing housing. Fortunately, battery energy storage technology with its flexible and modular configuration of racks means that rack heights can be adjusted according to need. The maximum height of the building in the SNS case is driven by the under-floor void dimension, floor thickness and height of the battery rack and switchgear equipment internal to the building.

7.3 Building Surroundings

Other external elements of the proposed development include a loading bay and an access road. This access road will connect to the existing site access to Woodman Close – no new permanent vehicular access is required. Where pedestrian access is required hard paving will be used otherwise the remaining land within the site boundary will be covered with 40mm shingle to maintain drainage and reduce weed growth. Sustainable drainage systems will be used to ensure there is no increase in flood risk to other areas.

To prevent vandalism, maintain public safety and meet the requirements of the Electricity Safety, Quality and Continuity Regulations (2002) perimeter fencing is required. This is to be 3m high “weldmesh” type fencing coloured Holly Green to reinforce the proposed landscaping and minimise the overall visual impact of the site.

In order to ameliorate the visual impact of the substation building and the 3m-high security fencing, a comprehensive landscaping scheme was designed and forms an integral part
of the design. The landscaping has been designed to provide a visual screen to the proposed development, one that will be effective throughout the year and comprises screen planting of trees and shrubs on three of the four sides of the compound as illustrated in Figure 12.

A 7m-wide planting strip has been located along the Woodman Close frontage, and a 6m-wide strip is proposed along the north-east boundary. Both these landscaped areas would include trees. Along the south-east boundary, the side of Clipstone Brook, it is proposed to introduce a 3m-wide planting strip, but with no trees. This was as a result of the fact that there is already a tree screen on the opposite side of the brook, and also a requirement of the Environment Agency to prevent blocking access to the brook for maintenance.

The extent of landscaping was increased from that initially developed, as a result of additional feedback from the local consultation during the planning process. Due to comments relating to the look of the existing substation, as part of further contributions covered in the s106 agreement, it was also proposed to include additional landscaping of the existing primary substation for the benefit of the community.

Figure 12 – Proposed Landscape Plan at Woodman Close
For safety and security purposes there will be external lighting within the site, in case that engineers need to visit the site out of hours. In order to reduce light pollution in the area, this is designed to face downwards and be designed to limit the light spread. The lights can be operated manually when there are authorised personnel on site and only for a limited period. They can also be triggered automatically if unauthorised access is detected to support the use of CCTV within the site.

Once the facility is in full operation, there is no need for storage installations to be manned, with only occasional visits similar to the existing substation. Maintenance engineers will arrive by van and will park within the compound. Access to the site during flood conditions will not be required.

### 7.4 Storage Facility Internal Civil Design

The overall concept for the facility layout design was to split the facility into two main sections, with one half housing the battery racks and one half housing the inverters and step-up transformers. This was to facilitate robust methods of restricting operational access to the different types of equipment, given the different operational training required for the various storage system components. Additional separate rooms were then included for the HV switchgear, SCADA and control equipment, fire-suppression equipment and Heating, Ventilation and Air Conditioning (HVAC) equipment, based on initial requirements and estimates.

The internal design and layout of the storage facility did not need to be presented as part of the planning consent process, which focussed more on the external visual impacts. However, an initial design for the layout was required to help determine the appropriate size and was developed in conjunction with the manufacturer. This initial layout is shown in Appendix 3, based on the maximum future expansion of the storage up to 8MW/24MWh.

The final layout designs of the facility, for both the initial configuration of 6MW/10MWh and potential future expanded configuration are shown in Appendix 4 and Appendix 5 respectively.

#### 7.4.1 Impacts on Future Expansion Limit

Once consents were received, this in effect locked down the building dimensions and constrains the maximum space available for the energy storage system, if further engagement with the Council was to be avoided.

It was following this stage that the battery cell supplier was changed due to financial issues with the initially appointed supplier. This meant that battery rack dimensions needed to be amended. Further design work with the new battery racks showed that a slightly increased footprint was needed which meant the full 24MWh could now not be accommodated in the current building size.

A lower-voltage DC-bus was chosen which meant fewer cells per rack, and hence a slightly lower rack height than originally anticipated (although there is the possibility of higher racks in the future). Also the requirement to accommodate a 5-panel 11kV switchboard with overhead cable access increased the floor space requirements for auxiliary equipment.

While technically feasible to expand the storage facility to accommodate up to approximately 20MWh with changes to the internal layout of the storage building, an internal review determined that this provided insufficient clearance between racks to allow for safe access and replacement of battery modules. The maximum future capacity that the building could safely accommodate, using this same technology, was therefore deemed as 8MW/17MWh, as shown in Appendix 5.

Based on the existing demand profile at Leighton Buzzard, the initial storage capacity of 10MWh is estimated to provide sufficient energy to handle around 3.5% proportionate growth from the highest historical peak demand observed in 2010.
Analysis demonstrated that a wide range of potential peak demand profiles can be supported into the future, and even when limited to 8MW/17MWh the facility could provide support for a high symmetrical morning and evening peak of limited duration.

It was also noted that there are likely to be significant storage technology changes over the coming years, which may further improve the expandability of the facility. For example a new generation of batteries with higher energy density may allow a more compact and space-efficient design.

For these reasons, the design of the building to accommodate at least the maximum practical number of battery racks, using “today’s” technology was considered to be the optimum solution. It was however proposed that the designed floor loading capability was not reduced as a result of this change, in order to leave flexibility to use a denser energy storage technology should changes in battery technology allow for up to 24MWh in the future.

7.4.2 Impacts on Internal Layout

A number of further design changes were made during the design process, compared to the initial proposed layout shown in Appendix 3.

As a result of the planning process, it was apparent that high levels of air-conditioning related noise would not be acceptable due to the proximity to residential housing. As a result, air-conditioning and ventilation extraction points were positioned on the southern face of the building, directed away from the road and residents. Significantly, the position of the inverter units and step-up transformers was then swapped so that they occupy the southern half of the building, with the battery racks now occupying the northern half. This was a result of the greater heat output of the inverter units requiring increased cooling with more ventilation available on the southern face of the building.

This change of orientation has implications for the installation of the equipment as it was originally envisaged that the large inverter units and transformers would be delivered through large access doors on the north side of the building, where the access road allows for delivery vehicles. The battery racks, being modular can be installed incrementally without the need for large access. The change of orientation meant this would no longer be possible from the southern side, and so installation will now be carried out by craning in the inverters and transformers through the roof of the facility, prior to completion of the roof.

Other factors amended during the design process included the internal cabling for the facility. Although the void underneath the building technically provided space to run cabling between the component parts, the high weights of the equipment meant that it was desirable to avoid penetrations in the floor which would comprise the integrity of the structure.

Each battery rack weighs around 1,500 kg, so for 10MWh configuration the weight of all the battery racks is approximately 198,000 kg and 459,000 kg for 24MWh of energy capacity. Each inverter unit is approximately 9,500kg and each step-up transformer is approximately 7,500kg.

To help avoid large penetrations in the floor, overhead cabling linking the inverters to an insulated overhead DC-busbar system across the battery racks will be used. While this increases the loading needed to be supported from the roof of the building, it prevents additional cost in providing for significant penetrations in the floor. An insulated overhead DC-busbar system also allows for simpler isolation and disconnection of battery racks from the system.

7.5 Storage Facility Safety Design

The safe construction, operation and maintenance of all operational sites is of utmost importance to UK Power Networks in line with its responsibilities as a licensed network operator and vision to be an ‘Employer of Choice’.
The predominant safety aspects that have needed consideration during the design process are as a result of the hazards and risks associated with new battery energy storage and inverter technology. While the risks and mitigating safety features associated with the ancillary plant, such as high voltage switchgear and transformers, is relatively well understood by UK Power Networks, there is less experience with those associated with energy storage technologies, with just one other battery energy storage facility installed on our networks to date. The main risk associated with lithium-ion battery cell technology is fire, and in particular uncontrolled propagation of fire from one cell to another. Whilst it was a requirement of the tender process that respondents provided solutions which had multiple layers of defence, starting with the fundamental design of the battery cells themselves, it is necessary to carry out analysis of worst case (and therefore highly unlikely) scenarios.

A number of exercises and studies have been carried out to ensure that risks are well understood, and mitigated as far as possible. These have included:

- A structured ‘So-What-If Test’ and analysis (SWIFT analysis) to help identify in a structured way the main hazards and risks of the complete storage system;
- Hazard Elimination & Management List review;
- Fire Risk Assessment Review of gas analysis from cell safety tests;
- Fire Engineering Analysis and Assessment; and
- Live Fire Test of battery trays, in order to inform models & extinguisher specifications.

The results of these activities, in conjunction with the UK Power Networks Fire Protection Engineering Standard for operational sites, have helped to guide the safety-related design features of the facility, which include:

- Adequate means of escape for all persons on the premises, via multiple egress routes from all zones within the facility;
- A zoned design providing areas of containment;
- Appropriate levels of fire resisting construction to contain any fire that occurs. In particular the main structural components of the building will have 60 minutes of fire resistance capability;
- Fixed fire detection and suppression system for each zone, utilising an inert gas suppression system to contain and control any fire in the event of a catastrophic failure;
- The means of escape will be illuminated and provided with emergency lighting;
- The premises will be provided with automatic detection and alarm, in accordance with BS5839 Part 2, for warning all persons on site in case of fire; and
- Hand held fire extinguishers will be provided, in locations to be agreed with the approval Authorities.

It should be noted that there are implications for the on-going operational costs of storage installations of such measures, as all necessary systems required as part of the general fire precautions are required to be satisfactorily maintained and periodically tested by specialist contractors to ensure adequate protection is maintained. However, DNOs are in a strong position to mitigate these risks and costs given their fire safety requirements across many operational sites.

The Fire Engineering Analysis study also provided an assessment of the implications of a worst case scenario fire. The analysis involved a 3D radiation model to predict the impact of a worst case fire on surrounding assets and property. From the study, it was concluded that a fire involving the storage system is not expected to result in damage or fire spread to adjacent facilities or properties, and that the safety factors included in the analysis provide adequate demonstration that a fire scenario necessary to cause fire spread is not credible. Although not the case for all storage technologies, it was also noted that it is acceptable to use water on Lithium Ion battery cell technology.

### 7.6 Storage Facility Electrical Design

A simplified single-line diagram of the electrical design for the
installation is shown in Figure 13 below, with the existing 11kV primary (Leighton Buzzard Primary) shown at the top left.

The storage installation will be named ‘Leighton Buzzard SNS’ and is shown schematically within the box towards the bottom. Starting from the common point of coupling, the storage facility connects to the 11kV busbars at the existing primary substation via two cables and switchgear which will be used to both protect the facility from network faults, and vice-versa. Two points of connection are to be provided, on each side of the bus section, to ensure that the storage device can contribute to security of supply even in the event that the bus-section circuit breaker is open, isolating one half of the busbar. For additional redundancy, an additional circuit breaker is provided on the incoming feeder within the storage installation for further protection and isolation.

Within the facility, the switchboard has four panels for connection to the transformers and inverter units. As described previously, three independent transformer and inverter unit groups will be initially connected, to provide the 6MW power rating, with the option for a fourth group to bring the power rating to 8MW. Each of these individual inverter feeders, labelled ‘11kV PCS 0X’ has its own isolating circuit breaker to allow disconnection and isolation of any individual 2MW group.

On the DC-side, each inverter will have battery 44 racks (consisting of 24 trays each) connected, each of which is individually isolatable from an overhead DC-busbar system. This helps the installation conform to UK Power Networks Distribution Safety Rules which ideally requires a point of isolation where a visual confirmation of disconnection can be provided.

Figure 13 – Single-Line Electrical Design
Learning Obtained, Conclusion and Recommendations
### 8.1 Learning Summary

The following table summarises specific learning that is relevant to the securing of planning consents at Leighton Buzzard and the impact on design.

<table>
<thead>
<tr>
<th>Ref</th>
<th>Learning</th>
<th>Impact</th>
<th>Possible Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The energy storage system supply chain is immature and evolving - existing procurement databases, such as Achilles do not provide the best view of potential suppliers (this also applies to other innovative technologies).</td>
<td>Suppliers with relevant solutions may be missed</td>
<td>Ensure a review and market research of the current market and alternative potential supply-chain partners to ensure new players are incorporated, as the marketplace is changing rapidly.</td>
</tr>
<tr>
<td>2.</td>
<td>There are several different ‘types’ of organisation that can supply energy storage systems, but each has expertise in different areas. It is not yet clear who will evolve to be the best type of lead supplier.</td>
<td>Suppliers with relevant solutions may be missed</td>
<td>Ensure market research is carried out. Consider the advantages and disadvantages of supply from different types of organisations.</td>
</tr>
<tr>
<td>3.</td>
<td>High capital investments for storage technology manufacturers, in combination with weak market conditions can cause weaknesses in financial stability.</td>
<td>Risks to financial stability of supplier partners</td>
<td>Ensure financial due diligence of technology partners, including sub-contractors.</td>
</tr>
<tr>
<td>4.</td>
<td>Commercially available credit reports are not adequate financial due diligence.</td>
<td>Risks to financial stability of supplier partners</td>
<td>DNOs and TNOs need to seek, and suppliers need to be willing to provide, information about financial stability throughout the entire supply chain.</td>
</tr>
<tr>
<td>5.</td>
<td>The planning consents process takes more effort, cost and time than expected. This turned out to be longer than statutory timescales.</td>
<td>Increased spend on planning process, and an extension of the time required to secure planning consents.</td>
<td>Consult with LPA early in the process. Ensure additional time and budget is factored in for alternative storage installation investigations.</td>
</tr>
<tr>
<td>6.</td>
<td>LPA policies can differ widely between areas; and policies can be set for land that is not within their ownership.</td>
<td>Inconsistencies between requirements for storage deployments</td>
<td>Support the dissemination of learning and education around storage to local authorities.</td>
</tr>
<tr>
<td>Ref</td>
<td>Learning</td>
<td>Impact</td>
<td>Possible Solution</td>
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<tr>
<td>7.</td>
<td>There is a need to be mindful of time constraints when in discussions with LPA over any section 106 agreement provision</td>
<td>Increase in time and cost of storage deployments</td>
<td>Appropriate budget should be considered where necessary</td>
</tr>
<tr>
<td>8.</td>
<td>Stakeholder concerns in the planning process from storage were more focussed on local issues, such as cycle ways, than specifics of the storage. Main themes were local issues, visuals and house prices</td>
<td>Higher costs of planning permission obligations</td>
<td>Explore and understand the local issues before developments and look for previous applications / press comments</td>
</tr>
<tr>
<td>9.</td>
<td>A tight-timescale can put pressure on negotiations relating to planning obligations</td>
<td>Improved timescales for storage deployments</td>
<td>Ensure engagement or planning process begins early. If at all possible build in time on the expectation of needing to appeal. See planning timeline in Appendix 2 as a guide</td>
</tr>
<tr>
<td>10.</td>
<td>Operational sites can potentially be retained ‘operational’ if boundaries are established early/historically, avoiding the requirement for planning permission for DNOs</td>
<td>Opportunity to increase the battery size in the future may be limited</td>
<td>If operational sites are required for long-term development they should be utilised where possible; although this will not be practical for third-party developers</td>
</tr>
<tr>
<td>11.</td>
<td>Footprints for similar battery technologies can differ between manufacturers. Hence, estimates of footprints for a certain energy capacity are only valid for a single supplier</td>
<td>This will limit making any changes to the external appearance of the structure, unless approval is obtained from the LPA</td>
<td>Allow for some margin in housing dimensions to allow for future expansion</td>
</tr>
<tr>
<td>12.</td>
<td>Having obtained planning consents for a site will lock down the external size and design of the building</td>
<td>May make obtaining planning approval harder</td>
<td>If unavoidable seek approval from the LPA</td>
</tr>
<tr>
<td>13.</td>
<td>Development control within local plan, may designate intended operational land for non-electricity undertaking purposes</td>
<td>Limited ability for purchasers to dictate DC-bus bar voltages; which in turn impact the height and footprint required for an installation</td>
<td>Ensure early understanding of the DC voltages and rack configurations</td>
</tr>
<tr>
<td>14.</td>
<td>Fundamental components, in particular the battery and the power converter, are likely to be inherited designs from other sectors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8.2 Conclusion

SNS is a Low Carbon Network funded project which is exploring the economics of using electrical energy storage to defer network reinforcement at a selected trial site adjacent to a primary substation in Leighton Buzzard. Having commenced in January 2013, the project runs for four years. The first half of the project timeline concentrates on the selection and design of the storage device and the construction and installation of the facility.

This report has documented early learning gained from the project, concentrating on the design and planning considerations which are necessary for large scale distribution connected electrical energy storage. It provides the considerations necessary in securing planning permission at the trial site and how this has impacted the design both at Leighton Buzzard and more generally the considerations that would be necessary for a DNO or other storage device developer to make when considering the use of distribution scale electrical storage.

The choice and design of a storage device is driven by a wide range of factors, but initially derived from the primary requirement of meeting or deferring a reinforcement requirement. A number of factors including location, capacity requirement including predicted and speed of growth, safety and economic benefits will define the need and selection of technology, who can provide it and how it should be accommodated. These design requirements will create various impacts each of which will determine more specific requirements in the design such as footprint, cooling requirement or detailed planning requirements.

Storage is most likely to be of value where the conventional upgrade is complex and costly, it would add significant over capacity, the constraint can be met by a small amount or additional capacity or will defer further investment for a reasonable period (5+ years) of time. Based upon analysis as a result of thermal capacity constraints and availability space, Leighton Buzzard emerged as the preferred site at which to build the storage device. Although alternative sites were considered, this site would provide most need and was best placed to demonstrate the economic tests required for the project. This location would require planning permission and this fact together with the specifics of the location drove some fundamental design choices. Primarily the proximity of the site to a local water course meant that the land was located in a high-risk flood location. It was also located close to residential housing. This meant that building design especially visual aspects would be important. The initial rating size of the storage device was determined to be 6MW/10MWh. This would initially provide an optimum amount of energy capacity and duration. Lithium Ion, which had good safety features relevant to the location, was the technology chosen and together with the size of building design would provide the capability to expand the device at a later date to 8MW/17MWh. This would be less than originally planned due to a necessary change of battery manufacturer which occurred following the competitive procurement process.

Planning permission is required for most new structures and buildings, and is also required for the change of use of existing buildings or sites. The planning system for England and Wales is set out in the Town and Country Planning Act 1990. It is almost certain that any new or temporary building, for example, the siting of shipping containers, required to house a grid-scale electrical energy storage system, will require planning consent. The exception to this is a site that has permitted development, for example, by virtue of its operational use, such as an operational substation with existing space within its existing curtilage. It is almost certain that any new distribution scale storage device would require planning permission.

A planning application for the Leighton Buzzard site was initially submitted to Central Bedfordshire Council in February 2013. It
followed a local consultation on the development which concluded that some changes to the visual aspects of the proposed building and its screening should be made. It was also necessary to provide significant detail on the required development and benefits of the chosen location over alternatives. These changes together with advice received from the LPA and Environment Agency on provisions necessary to mitigate flooding had been incorporated in the application. A section 106 agreement was negotiated with the LPA and became a condition of the planning approval that was finally granted, following an extension to the statutory timescales, in June 2013.

The external design of the Leighton Buzzard building was fixed as part of the planning application. It had developed from the equipment it was intended to house, flood mitigation requirements and the need to build something that would be acceptable in close proximity to residential housing. To further mitigate any adverse visual concerns extra tree planting was incorporated into the overall design.

The main learning points centred around procurement and the selection of a storage technology provider as well as the need to take due regard in all aspects of local authority planning, including the need to be vigilant on reviewing local plans and ensuring that a planning application is robust on submission.
Appendix 1
Residents Consultation Document
Proposed substation expansion for Leighton Buzzard

Introduction
UK Power Networks (Operations) Limited ("UK Power Networks") on behalf of Eastern Power Networks plc, the licensed distributor of electricity in the East of England, plans to build an extension to its existing substation at Woodman Close, Leighton Buzzard.

This leaflet explains the reasons why an extension to the substation is needed and gives a brief description of the proposals. Preliminary advice has been sought from Council officers, Members and the Environment Agency. Comments from the local community are now being sought before an application for planning permission is submitted to Central Bedfordshire Council.

Woodman Close Substation, Leighton Buzzard
The existing Woodman Close Substation is situated on the north-east side of South Street, between Clipstone Brook and Woodman Close, as shown in Fig. 1: Location and Site Plan. The adjoining land was acquired in 1970 for the purpose of providing electricity and potential further expansion. Whilst the land was not required for electricity supply purposes, it was left as open land and, at one time, was used for allotments by local residents. That use has now ceased.

The Need for the Substation Expansion
The Woodman Close Substation is reaching its capacity due to an increase in demand for electricity in the local area. To maintain reliable power supplies into the future, the substation needs to expand. After assessing a number of potential sites using a series of technical, engineering, environmental and planning criteria, Woodman Close was identified as the only suitable site to provide this essential infrastructure, one that would incur the least disruption to the existing supply and be built within the necessary time frame.

Close proximity to the existing Woodman Close Substation is absolutely essential. As the site is already in our ownership and we do not need to acquire additional land, it also allows us to meet the regulatory requirements to deliver best-value to all our electricity customers in Bedfordshire and the East of England. As the existing and new facilities can all be enclosed within a secure compound, this offers the highest level of security for continued electricity supply as well as from theft and vandalism.

Fig. 1 Location and Site Plan

The existing Woodman Close Substation
New technology
The extension to the substation will use an electrical storage device in place of traditional substation equipment. This new technology provides a more sustainable way to reinforce the electricity network. It reduces the need to create additional power lines feeding the substation and removes the need to install new transformers on the site. Electrical storage supports the increasing use of electricity generation from wind turbines and solar panels, smoothing out the peaks and troughs on the local network caused by the varying strength of wind and sun.

Proposed development
We are the freehold owner of 11,000sq.m of the land outlined in blue in Fig.1. Planning permission will be needed for the new area of development for the extension to the substation. This area (outlined in red in Fig.1 and covering an area of 3,000sq.m) adjoins the existing substation compound on its north-easter boundary.

The proposed development includes a single-storey building with a footprint of about 40m x 20m and a maximum height of 8.3m above ground level. The shape and volume of the proposed building is dictated by the electrical plant that needs to be housed within it. The substation compound will be surrounded by a 3m-high security fence and landscaping.

Flood prevention measures
Except for a small part of the Woodman Close Site in the northeastern corner that is above the flood plain, a large proportion of the site is in a flood risk area. Consequently, special precautions have to be taken in the design of any development which needs to be raised above predicted flood levels. Following consultations with the Environment Agency, the proposed extension to the substation incorporates a 2m-high void beneath the elevated ground floor, thus raising the overall height to 8.3m above ground level.

Design and landscaping
The proposed building has a mono-pitched roof and a patterned facade on three sides. The facing material will be colour-coated metal panels. The choice of colours of the building could be changed as a result of this consultation.

The proposed building has an elevational design that is intended to help it blend in with its surroundings and to minimise the visual impact as far as possible. The patterned design aims to introduce an interesting pattern to the streetscape. We will use good quality facing material that will require minimal maintenance.

It is proposed to screen the development using landscaping along the Woodman Close north-western elevation and the northeastern elevation facing the open land. This screen, which will be a minimum of 5m deep, will include trees and evergreen shrubs.

Impacts

Noise
There will be no increase in noise above the present levels resulting from the proposed expansion of the substation.

Lighting
Minimal security lighting will be used in order to minimise disturbance.

Wildlife
A recent wildlife survey of the site found no protected species. Our Ecologist has recommended that (i) the river corridor should be reserved for amphibians; and (ii) part of the vacant land should be retained for toads, frogs and other wildlife. This wildlife area will not be landscaped but managed to prevent overgrowth.
View from Woodman Close

Existing

Proposed (illustrative only)

View from the Vacant Land

Existing

Proposed (illustrative only)
Health and Safety
The type of energy storage system to be installed employs a safe form of technology. The extension to the substation will exceed the stringent health and safety requirements and fire prevention measures required for substations.

EMF’s
This facility is primarily a Direct Current (DC) facility, therefore there will be no increase in the level of EMF’s (Electro magnetic fields) above the present levels from the proposed expansion.

The Substation in Operation
The proposed building will only house electrical plant. Except for occasional visits for inspection and maintenance purposes, no personnel will be working on the site. Except during the construction and commissioning period, no lorries are likely to visit the site.

Vehicular Access
The vehicular access into the new compound will be via the existing substation access point. There will be on-site parking for occasional visiting operators.

Community Benefits
The extension to the substation will include sustainable technology to house a low carbon, energy storage system. A key benefit to the local community is our increased ability to provide reliable power supplies in the future.

Shared Footpath and Cycleway
The Council wishes to secure a strip of land alongside Clipstone Brook for a shared footpath/cycleway on part of the Eastern Power Networks site (see Fig.1). The detailed route and lease arrangements are to be discussed with the Council.

About UK Power Networks
UK Power Networks distributes power to a quarter of Britain’s population through its electricity networks serving the East of England, South East and London. The company’s 5,000 employees are dedicated to delivering a safe, secure electricity supply to about eight million homes and businesses via its network of substations, overhead lines and underground cables.

The industry regulator, Ofgem, places conditions on UK Power Networks, for example, it must ensure safe and reliable power supplies to its customers, and cater for future technological changes and growth in demand. This year UK Power Networks is investing £360 million in its electricity networks and around £1.8 billion in the five years to 2015.

Next Steps
We are currently preparing the scheme for a planning application submission, taking into consideration advice from the Council, the Environment Agency and the public. It is hoped that an application will be submitted during November 2012, with the construction works starting in 2013.

Your Comments
We welcome your comments on the proposal on issues including:
• the design and colour of the cladding;
• the location of the shared footpath/cycle-way;
• the use of the surplus Eastern Power Network land for as long as it is not needed for electricity distribution.

Contact us
If you have any queries or comments, please email us at: LBSubstation@ukpowernetworks.co.uk or write to:

UK Power Networks
Leighton Buzzard Substation Enquiry
c/o Strategy and Regulation, 1st Floor North
Energy House
Hazelwick Avenue
Crawley
West Sussex RH10 1EX
Appendix 2
Planning Timeline Summary
Appendix 3
Original Building Layout Design for 8 MW/24MWh
Appendix 4
Final Building Layout Design for 6 MW/10MWh Project
Appendix 5
Future Potential Building Layout Design for 8 MW/17MWh Project