FEASIBILITY REPORT

STORAGE ARRANGEMENTS FOR BRETHERTON

PREPARED BY

StorTera

FOR

Energy Local

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1. INTRODUCTION

StorTera has been commissioned by Energy Local to investigate the feasibility of an innovative storage arrangement to utilize renewable generation from GA Pet Food Partners as part of an Energy Local Club for residents in the nearby village of Bretherton in Lancashire. The work carried out by StorTera in this study involved developing a high-level design for the battery system and connection arrangements, determining suitable sizing and providing budget costs for the overall system.

This report summarizes the work carried out and identifies possible ways to optimize the arrangement to meet Bretherton's requirements and facilitate the upfront capital cost.

StorTera is an Edinburgh based energy storage specialist with expertise in the design and supply of a range of battery technologies along with associated power electronics, controls and software. To date we have installed our products for a range of customers in the UK, Canada and South Asia. We use very safe lithium ferro phosphate (LFP) battery technology which is thermally stable and does not contain rare earth materials like Cobalt, which is often sourced unethically from Africa.

StorTera has been involved in the development and demonstration of multiple innovative smart energy network projects involving battery systems, so are very well suited to design and deliver the bespoke connection arrangement needed for Bretherton.

2. PROPOSED CONNECTION ARRANGEMENTS

Energy Local provided the network diagrams from Electricity North West (ENW), the distribution network operator (DNO) for the Lancashire area. The relevant information from the ENW maps has been summarized in Figure 1 below.

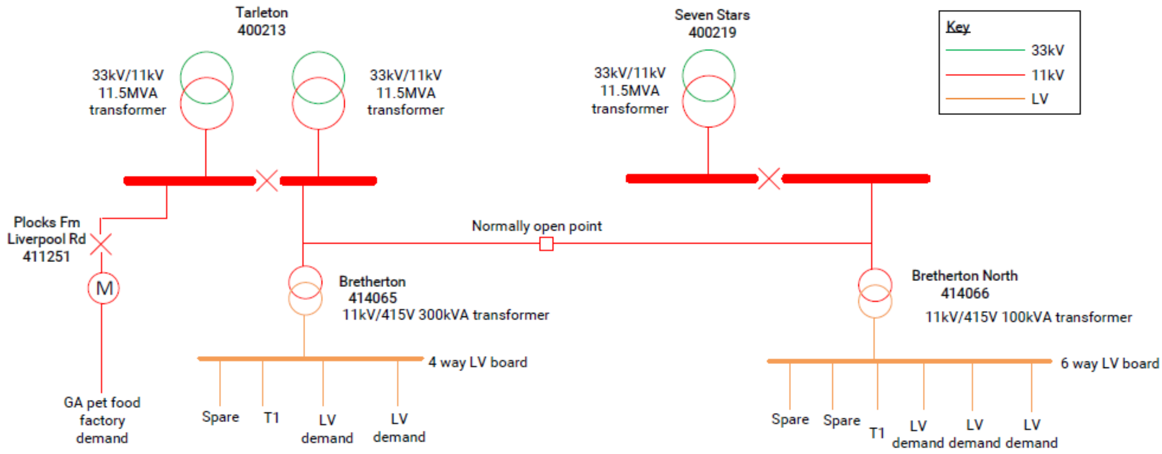

Figure 1: Diagram of existing network

The proposed connection arrangement must allow the battery system to charge from an 11kV connection from GA pet food's renewable generation, and discharge to supply low voltage (LV) residential customers connected at two different distribution substations, Bretherton and Bretherton North. The two distribution substations are fed from different primary substations, as shown in Figure 1, so the proposed connection arrangements required a separate connection from the battery system to each distribution substation.

The proposed battery system arrangement would consist of a separate battery sub-system for each distribution substation. Each sub-system would have two batteries so that one battery can charge from renewable generation while the other discharges to supply the residential loads. A set of two automatic transfer switches (ATS) would allow the system to switch between the batteries, and this is explained in further detail in Section 3. The switches would be mechanically and electrically interlinked so that the LV and 11kV connections could never be electrically connected.

Each battery would be a steel container (size depending on battery capacity) containing LFP battery modules and a bi-directional power conversion system (PCS) to charge or discharge the battery modules. Figure 2 shows an example of a 500kWh system in a 20ft container, and Figure 3 shows a 150kWh system in a smaller steel enclosure.

Figure 2: Example photo of 20ft StorTera battery container

Figure 3: Example photo of small battery enclosure

Assuming the battery system is located as close as possible to Bretherton substation, an LV connection from the battery to Bretherton North substation would be around 400m distance. Long cable runs at low voltage result in higher power losses, and higher cable costs due to the larger conductor size required for the LV grid connection to Bretherton North.

An alternative option would be to have two separate battery sites, each located as close as possible to a distribution substation, as shown in Error! Reference source not found.. This would result in higher capital costs for the battery sites, additional length of 11kV private wire and additional 11kV/415V transformer but may be beneficial in the long term due to the reduced power losses.

3. SYSTEM CONTROL

3.1. Control Strategy

The control strategy for the battery system would involve switching the battery connections so that one battery would be charging from available generation and one would be discharging to meet demand at the same time. The switches would operate when one of the batteries reached a defined charge level, termed the "handover state of charge (SoC)".

At times, typically in summer when solar generation is high, the available generation cannot be used for charging when one of the batteries is fully charged and the other is at a high state of charge. In this case any available generation would be used for GA pet food loads or exported to grid until the second battery discharges to the handover SoC.

At other times, typically in winter when available generation is low, demand cannot be met by discharging the battery when one of the batteries is at its minimum level and the other is at a low state of charge, as shown in the second example. In this case demand would be met by importing from the grid until the second battery charges to the handover SoC.

The handover SoC parameters of the control strategy would be optimized based on the actual generation and demand data and the agreed buy/sell price for imported and exported energy. The control strategy would vary the handover SoC throughout the year to minimize export and import.

3.2. Control System

StorTera has developed a novel AI platform, the tri-layer AI controller (TRAICON), that can provide demand side response functionality as well as respond to external signals such as grid, weather, or renewable generation data. This platform includes our proactive BMS that optimises batteries at the cell level. It uses neural network-based machine learning to analyse large datasets and proactively control all the connected systems. The TRAICON uses AI at distributed levels and uses centralised data to make accurate predictions and provide control.

The three layers function as follows:
The top-tier AI looks at weather patterns, renewable generation data, and time-based human behaviour for decision making. For example, to predict the next day's PV generation and decide how much energy to store in the battery for optimum results, the TRAICON uses AI to analyse satellite imagery, solar PV data, battery voltage levels and load usage patterns.

The mid-tier of the TRAICON utilises a collection of large data sets from residential loads, commercial loads, residential PV generation, commercial renewable generation, commercial load profiles, and grid utility load profiles. The AI neural networks are configured using tensor flow to analyse data and to make decisions.

The lower tier AI BMS increases battery cell lifetime and efficiency of the battery system. Distributed controllers in the BMS are used to run artificial neural networks (ANNs) for control outputs. Dalhousie University tested the BMS and concluded that it provides a very high efficiency of 96.2% for battery modules.

The TRAICON controller can integrate with third party platforms with a range of tools including our API. This has been demonstrated recently by StorTera's award winning Alba Nova project which was part of the Power Forward Challenge project in Nova Scotia. In this project, StorTera developed a highly flexible smart grid that focused on the needs of consumers first as well as leveraging benefits for the local grid operator. StorTera designed and integrated a wide range of hardware, software and controls for residential and commercial battery systems, and modelled and tested several operational strategies to assess their benefits and determine the optimum control strategy for stakeholders.

The inclusion of an intelligent control system such as the TRAICON would enable maximum utilisation of energy storage assets by predicting when peaks of demand and generation will occur based on grid and weather data feeds. It can then ensure that the required amount of battery capacity is available to store as much of the wind or solar available and/or ensure battery is fully charged before peak demand periods.

The control system would need to receive data on the current generation and aggregated village demand at minimum frequency of every 30 minutes but can handle data frequencies of as high as 1 per second. Increased data frequency would improve the results for AI predictions and allow more accurate matching of the battery charge/discharge with the current demand/generation.

4. BATTERY SIZING SIMULATION

A model of the proposed system arrangement was used with the simulated generation and 2022 village demand data provided by Energy Local to determine suitable sizing for the battery system.

The outputs of the model were as follows:
1) Exported energy: when generation cannot be used to charge the battery
2) Imported energy: when demand cannot be supplied from the battery
3) Number of switching operations: the amount of times the switches operate to change battery from charging to discharging or vice versa

The model was run for different battery sizes and values of handover SoC to study how the change in parameters affects the outputs. The simulation results for 2MWh and 4MWh total capacity at different handover SoC are shown in the table below.

The results show the exported energy as a total annual value in MWh, as well as a percentage of the total available renewable generation. The imported energy is shown as a total annual value in MWh, as well as a percentage of the total annual village demand.

Modelled parameters		Results		
Battery capacity	Handover SoC	Total export (MWh, %)	Total import (MWh, %)	Avg no. of switching operations per switch
2MWh	50%	1,153 MWh, 56.05%	74 MWh, 7.43%	2,617
2MWh	70%	1,142 MWh, 55.52%	65 MWh, 6.56%	3,178
2MWh	90%	1,139 MWh, 55.37%	62 MWh, 6.25%	5,661
4MWh	50%	1,119 MWh, 54.41%	45 MWh, 4.50%	1,380
4MWh	70%	1,115 MWh, 54.18%	40 MWh, 4.02%	1,815
4MWh	90%	1,110 MWh, 53.94%	36 MWh, 3.66%	3,484

Table 1: Battery sizing simulation results

The results show high handover SoC results in lower values for imported and exported energy but requires more switching operations, resulting in a higher operating cost as the automatic transfer switches would need to be replaced more frequently. A higher battery capacity would also reduce the amount of imported and exported energy, but the additional capital cost of a bigger battery may outweigh these benefits.

The simulation uses a total battery capacity for the combined demand of Bretherton and Bretherton North, as the split in demand between these two LV substations was not known. For costing purposes, the split was assumed to be 50/50, so the four battery systems would be equally sized.

5. BUDGET COSTS FOR INSTALLED BATTERY SYSTEM

5.1. Battery Installation Works

Site civil works would likely take 3-4 weeks and involve:
- Construction of foundations for the battery containers (either concrete pads or screw piles, depending on ground conditions)

- Installation, including foundations, of a pre-fabricated GRP enclosure to house the grid connection, metering, electrical board and control equipment
- Installation of underground cable ducts and earthing
- Construction of a minimum 1.8m high security fence and fixed CCTV cameras

Following completion of the civil works, the battery containers would be delivered to site and offloaded onto the foundations using a crane. A temporary access road may need to be constructed to provide access for the crane, depending on the site, which would be removed and made good after delivery.

Once the battery containers have been installed the remaining works would involve installing the electrical equipment, power and communications cables, and testing and commissioning the overall system. This would take around one month but would not be disruptive works for surrounding residents.

5.2. Budget Costs and Options

Budget costs have been estimated for a few different battery sizing options and presented in Table 2 for comparison. Values have been redacted for the public facing version of the report, however each option has been ranked from lowest to highest cost for comparison purposes.

		Total cost ranking (1 – lowest, 5 – highest)
Option 1: 2MWh, one site		1
Option 2: 2MWh, two sites		2
Option 3: 4MWh, one site		5
Option 4: 2MWh, one site	Stage 1: 4 x 250kWh	4
	Stage 2: 4 x 250kWh	
Option 5: 2MWh, one site	Stage 1: 2 x 500kWh	3
	Stage 2: 2 x 500kWh	

Table 2: Budget cost comparison for different options

Battery system costs include all costs related to the supply of the battery containers, including the hardware itself, delivery to site and StorTera labour costs for design, testing, implementing control strategy, and on-site installation support and commissioning.

Installation costs include the electrical and control equipment needed on site (automatic transfer switches, PLCs, communications, distribution board, cabling, G99 relays), as well as the civil works listed in Section 5.1 above.

These are capital costs for supply and installation only, and do not include for any ongoing costs such as communications provision, security monitoring or maintenance costs. These costs would vary depending on size of the system, number of installed sites and control strategy for the batteries, so could be estimated once a suitable option has been selected.

The budget costs do not include any equipment outside of StorTera's scope as outlined in **Error! Reference source not found.**, such as the LV grid connection works, 11kV private wire connection or 11kV/415V transformers.

It should also be noted that the budget costs include some contingency for future price increases but this is very approximate as it is not possible to accurately estimate prices more than 6 months into the future. The purpose of the budget costs presented here are to show how number of sites, staging of installation and battery sizing affect the costs to allow a suitable option to be chosen for more detailed consideration.

5.2.1. Options 1 and 2

Options 1 and 2 are for 2MWh total battery capacity, which would consist of four 500kWh battery systems, each in a 20ft x 8ft container. Option 1 is around £100k cheaper as it assumes all equipment would be installed at a single site. Option 2 estimates the additional installation costs to develop two separate sites, such as increased civils and some duplication of electrical and control equipment, as well as increased labour costs for the design and on-site activities. However, as explained in Section 2, having two separate sites where each is located as close as possible to the corresponding LV substation would result in reduced power losses which may offset the additional capital cost.

5.2.2. Option 3

Option 3 is for 4MWh total battery capacity, consisting of four 1MWh battery systems, each in a 40ft x 8ft container, at a single site. The battery system cost is significantly higher, due to the increased battery capacity, and the installation costs are higher due to the increased civil works for 40ft containers. It is expected that the additional capital cost would not be sufficiently compensated by increased revenue from utilizing more renewable generation / reducing import from grid, so this is not an optimal option and is presented for comparison only. However, if the capital cost could be financed at the project outset, this may be the most cost effective option to accommodate the predicted increase in village demand in 2030.

5.2.3. Option 4

Option 4 considers a two-stage installation approach where four smaller 250kWh battery systems are installed in Stage 1, then another four 250kWh battery systems are added in a future Stage 2. This is a possible way to demonstrate the project with a lower battery capacity initially, resulting in lower CAPEX at the beginning of the project, and still provide the flexibility to increase capacity in future. However, it should be noted that StorTera have not yet tried and tested connection of additional battery systems at a later date, so further studies and testing would be required to confirm this is feasible if this approach was of interest. This two-stage installation approach is around £600k higher than completing the works in one stage (Option 1) but may make it easier to finance in 2 smaller stages.

The costs for Option 4 assume the installation in Stage 1 includes all works needed to enable the future battery systems are carried out in the beginning (civil works, electrical installation etc) so that the installation works in Stage 2 consist of installation support, on-site testing and commissioning only. The battery system costs are higher for the same total capacity as Options 1 and 2 due to the system comprising of 8 small systems instead of 4 larger systems.

5.2.4. Option 5

Option 5 considers a simpler, cheaper way to reduce upfront CAPEX than Option 4, by supplying only one LV substation initially, either Bretherton or Bretherton North, with only two 500kWh battery systems needed on a single site. For future expansion, the site could either be extended or a second site developed to add two new 500kWh battery systems for the other LV substation.

The costs for Option 5 assume Stage 1 and Stage 2 installations are at the same site, and the installation in Stage 1 includes all works needed to enable the future battery systems. The staged approach of Option 5 costs around £130k more than the comparable Option 1, but again may make financing the project easier. The downside is that only customers from one substation could participate in the first stage of the project.

6. COMMERCIAL

There may be additional ways to earn revenue from the battery system, other than from supplying demand customers. Potential ways to earn revenue may include:

- Offering flexibility services to the DNO
- Providing grid services to National Grid
- Trading based on a time of use tariff
- Reducing GA pet food's peak demand (peak shaving)

These have not been considered in this feasibility study as more information would be required on the existing and proposed grid connection arrangements, energy supply contracts and PPA, as well as getting a clear understanding of Bretherton's long term objectives for the project.

If shortlisted as a battery supplier for the project, StorTera would be happy to enter discussions on possible innovative commercial arrangements to support financing the upfront capital cost of the battery system. There are a number of possibilities that could be explored, such as StorTera sharing the upfront capital cost and providing an ongoing service to optimize the system, in return for a portion of the resulting revenue and/or a lease fee. This would be best discussed directly with the relevant parties when the project plans and timescales are more clearly defined.

In addition to supplying LFP battery systems, StorTera's main business focus is development of an extremely promising novel flow battery technology which has many benefits over mainstream lithium battery technologies including long lifetime (over 30 years), high efficiency and low capital costs. A 200kW, 1.6MWh pilot demonstration project is planned for installation in 2024 and following this successful demonstration StorTera plan to commercialize the product. Depending on the desired timescales of the Bretherton Energy project, the proposed design could be implemented using StorTera's flow battery to provide the benefits of a more sustainable battery technology that provides performance and cost benefits compared to an LFP system as presented in this report.

7. CONCLUSION

The main aim of this feasibility study was to provide a high level design for the storage arrangements to meet the operational requirements of supplying two Bretherton substation loads at low voltage from a battery which is charged using renewable generation at GA Petfoods via an 11kV private wire. A suitable high level design has been provided and described in Section 2.

A simulation model was produced for battery sizing purposes and concluded that a total battery capacity of 2MWh would be sufficient to meet the village demand in 2022, although it is not possible for 100% of the demand to be provided from the battery year round, due to the seasonal variations in renewable generation. Different control strategies for the battery were modelled to determine how the control parameters affect the total amount of renewable generation that can be stored and demand that can be supplied. An increased battery capacity of 4MWh was also simulated to determine whether this would provide better results, but it was concluded that the improvement in results would not sufficiently justify the increased capital cost.

The use of StorTera's proprietary AI-based control system would implement and optimize the control strategy based on day-ahead predictions for demand and generation.

StorTera also provided budget costs for a 2MWh system installed at one site, as well as some other options to show how costs would vary if the system was separated into two sites, or whether the installation was carried out in two stages to facilitate project financing.

This feasibility report shows that there are many different possible options to implement a suitable battery system arrangement for Bretherton, and StorTera would be delighted to continue discussions to help refine and optimize the options to meet the end customers' requirements.

StorTera has proven experience in developing flexible and innovative smart grid solutions to maximize benefits for the end users, as well as the capability to specify, design and supply all hardware, software and controls required to deliver bespoke arrangements for Bretherton.