STORENET INNOVATION PROJECT CLOSE-OUT REPORT

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PROJECT START DATE: (Q1, 2018)
PROJECT END DATE: (Q4, 2020)
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1. PROJECT SCOPE AND DESCRIPTION

ESB Networks in its role as Distribution System Operator (DSO) will be a key enabler in the transition towards a low carbon energy society. The roll-out of clean energy enabling technologies, including residential scale battery energy storage is expected to increase over the coming years as technology costs fall and the potential of these technologies is better understood across all stakeholders in the energy industry.

The International Energy Research Centre (IERC, a research performing organisation) ESB Networks (Distribution System Operator), Solo Energy (Virtual Power Plant Aggregator), and Electric Ireland (Electricity Supplier) formed a consortium, under the StoreNet project, to develop and deploy an intelligent Virtual Power Plant (VPP) consisting of distributed energy storage (batteries) installed at residential settings on the distribution network with the intention of maximising learnings on the potential benefits from the energy storage system. Led by the IERC, the consortium-wide objectives of this demonstration were threefold:

1. To evaluate potential value propositions for customers, tied to battery storage systems;
2. To understand the impact of and benefit of distributed storage, in a residential setting, to the network; and
3. To propose business model(s) for the VPP, that would offer mutual benefits to the network operator, utility supplier, VPP aggregator and the customer;

For the purposes of the StoreNet Project, the VPP was established with the objectives to

(i) store and effectively manage renewably generated electricity, whether generated onsite or elsewhere on the local distribution system;
(ii) deliver the stored energy to consumers/prosumers in peak demand periods; and
(iii) serve the needs of the grid;

The VPP consisted of twenty Sonnen lithium-ion battery systems (10 kWh, 3.3 kWp) integrated through Solo Energy's ICT platform. The twenty systems were installed in twenty customer premises in the Ballyferriter area of West Kerry. Seven of the properties were also equipped with Solar PV (2.1 kWp) arrays.

This project close-down report focuses on objective 2 above, and in particular, on the impact of battery storage on the LV / MV network.

The main responsibilities and objectives of ESB Networks within the StoreNet Project were to:

- Advise Solo Energy (the VPP aggregator) on appropriate trial locations on the distribution network;
- Facilitate the installation of battery storage on the distribution network; and
- Quantify the flexible services which battery storage could offer the DSO, in particular for voltage support and peak load shaving;

ESB Networks was motivated to join this IERC led consortium as it recognised that with the increasing installation of RES (Renewable Energy Source) technologies such as solar PV, and clean energy enabling technologies such as heat pumps, batteries and electric vehicles that, as Distribution System Operator (DSO), it could require to reinforce parts of its networks to cope with ever more volatile electricity consumption and distribution-connected generation patterns. In order to rationalise investments while maintaining quality of service to customers, ESB Networks wished to learn from this StoreNet project as to whether a battery based VPP might offer alternative solutions to traditional network reinforcement. The expectation was that trials of the battery technology would enable DSO to:

- Smooth generation and consumption peaks to increase the capacity of existing networks (saving investments);
- Enhance power quality (reactive power, voltage);
- Limit losses; and
- Perform local balancing;

2. CHANGES TO PROJECT (SCOPE / TIMELINES / DELIVERABLES / BUDGET / RESOURCES)

The StoreNet Project was originally intended to be completed at end Quarter 2, 2020. However, project timeline was extended until end Quarter 4 2020 for the following reasons:

- Delays to execution of specific scenario tests caused by Covid-19,
- The request by project partners for a complete 12-month period of data upon which to perform data analysis; and
- To perform additional scenario testing of the battery storage systems;

3. PROJECT ACTIVITY & RESULTS

Choice of Trial Location

It was decided to trial the StoreNet project on the Dingle Peninsula for a number of reasons including:

- The existence of an engaged energy community, through the workings of the Dingle 2030 initiative;
- The selection of Dingle as the location of ESB Network's Dingle Electrification Project and potential for sharing of learnings associated with battery trials under both projects;

ESB Networks' Dingle Electrification Project is seeking to understand the impact of a range of clean energy enabling technologies (Solar PV, residential-scale battery storage, air source heat pumps, smart EV and vehicle to grid chargers) on the electricity network and the potential for these technologies to be operated in a flexible manner so as to minimise such impacts and provide support to the local network.

Co-location of project trials on the same part of the network better affords the opportunity for leveraging local expertise and learnings in these technologies.

FIGURE 1 - MAP HIGHLIGHTING DINGLE PENINSULA & STORENET TRIAL AREA (ENCIRCLED)

With the Dingle Peninsula (Figure 1) selected as the general location for the StoreNet project, the next challenge was to identify the most appropriate location on the peninsula's network where this small-scale trial would have the potential of uncovering real learnings.

A number of network studies were carried out using the SynerGee software on all feeders from Inch and Dingle network stations. The worst three areas, in terms of voltage, were selected and presented to the local CSS (Customer Services Supervisor) for consideration. The Ventry MV circuit from Dingle 38 kV station was chosen for the StoreNet trial as that presented the greatest power quality challenges, in particular with respect to voltage problems in that area and it was considered likely that trials of the battery-based VPP under particular modes of operation might provide learnings on the potential to effectively manage some of the local network problems without the need for traditional reinforcement.

In particular this study highlighted that an additional winter peak (30% on top of normal winter load) seemed to occur in Dingle town between 26th December and 31st December each year. This peak quickly falls away in the new year. Even ignoring this peak, there is not a satisfactory standby for the Ventry C15 line during the winter period. When providing standby to Ventry C15 line from Ballydavid E36 line, the voltage drops to 79.8%. As such, the conditions experienced on the network at Ballyferriter appeared to align with a number of the test scenarios that were considered possible with the VPP, i.e. peak shaving and voltage support.

Red shows feeder is out of standard:

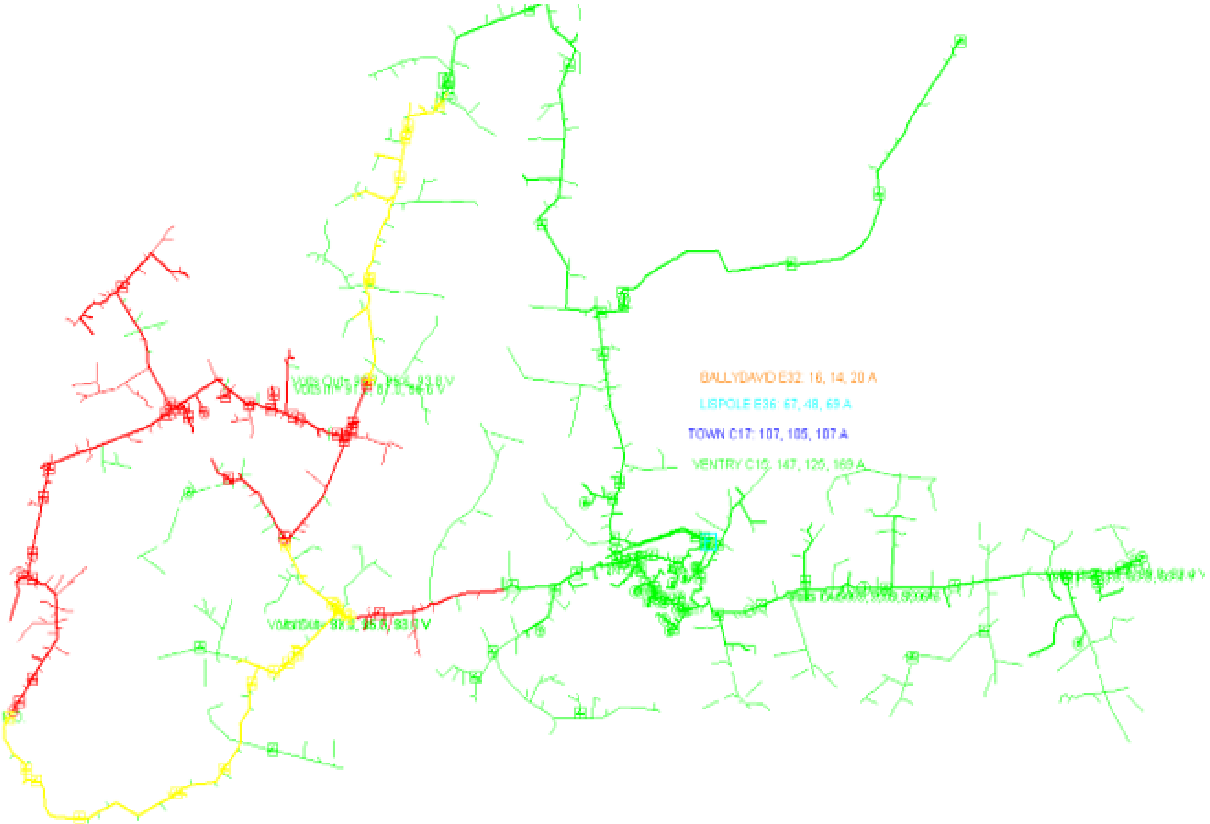

FIGURE 2 - WESTERLY PART OF ELECTRICITY NETWORK ON DINGLE PENINSULA

Figure 2 above shows the network map for the trial area and highlights the segment in red (Ballyferriter) where voltage challenges existed.

Figure 3 below shows the network at Ballyferriter and the location of the 20 participants on the trial.

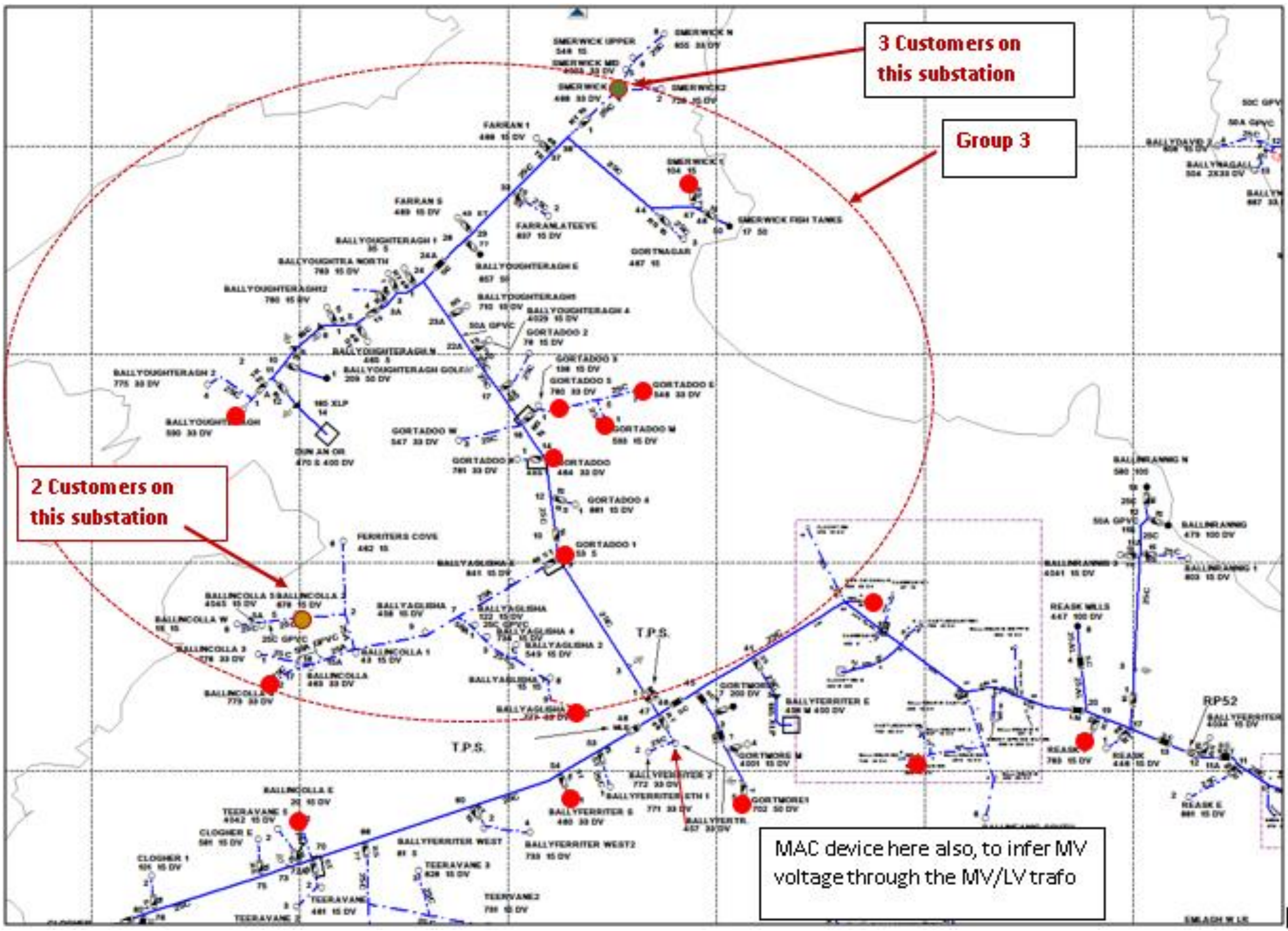

FIGURE 3 - NETWORK AT BALLYFERRITER

Facilitating Installation of Battery Storage on the Distribution Network

ESB Networks had a number of key roles in facilitating the installation of the battery storage on the distribution network:

- Financial contribution to the cost of procuring the batteries;
- Supporting the development of a set of terms and conditions, to govern participation on the trial;
- Supporting the identification of competent locally based contractors to perform the installation works so as to retain this technical capability and competence in the local area;
- Installation of remote read interval meters at all trial participant properties and subsequent reconfiguration of a number of meters to one-minute interval recording;
- Development and operation of profile meter data collection processes; and
- Procurement and installation of LV vision devices at multiple locations across the network at Ballyferriter to support identification of impacts of battery operation on the LV network;

FIGURE 4 - SONNEN BATTERY INSTALLED AT TRIAL PARTICIPANT PREMISES

Quantify the Flexible Services which Battery Storage could offer to the DSO

The services ESB Networks wanted to trial were:

1. Active Power Management – Where the DSO would have the facility to call for voltage support from all batteries using reactive power. This trial was attempted in April 2020
2. Peak Lopping – Where the DSO would have the facility to call on all batteries to export close to evening peak time (5-7pm) so as to meet load requirement at the consumer's premises and spill any surplus onto the network. This trial was carried out in November 2020.

These objectives were the focus of tests carried out by Solo Energy (VPP Aggregator) for ESB Networks under its contractual arrangement with the battery system provider. An initial phase of testing was designed to determine the capability of the batteries to support active power management. These tests were proposed to be carried out over the period April 7th to April 23rd, 2020.

A second phase of testing was designed to determine the capability of the battery based VPP to reduce the peak demand on the network. It was intended that these tests would be carried out close to the winter peak, however, owing to the expected unavailability of the VPP platform at that time, these tests were brought forward to last week in November 2020.

The learnings from both phases of testing are outlined in section 4 below.

Active Power Management

An initial phase of testing was designed to determine the capability of the batteries to provide voltage support by controlling reactive power output at the inverter. These tests were proposed to be carried out over the period April 7th to April 23rd, 2020.

These tests were designed on the understanding that Power Factor correction should have been possible via use (control) of inverters. In the April tests it was attempted to set a power factor of 0.85. However, these tests failed so it was not possible to prove or disprove.

Upon investigation by the VPP Aggregator, it was determined that a software issue prevented execution of these tests. Whereas active power was injected, reactive power was not and as a result a negative Power Factor (outside the -1 to +1 range) was observed and not the positive 0.85 as intended.

From a VPP Aggregator perspective the active power injection worked correctly, and it believed the inverter to be capable of technically providing reactive power support services. Following an investigation, the VPP Aggregator identified that this was a software problem. The VPP Aggregator was of the view that the software problem most likely involved the specific version of the battery provider's IoT API which was used by the VPP for the StoreNet project and that this likely caused the difficulty in performing the tests.

Both ESB Networks and the VPP Aggregator were extremely disappointed that these tests were not capable of being executed, due to a limitation of the specific version of the API software within the battery system, being used by the project. To compound this software problem, the contract in place between the VPP Aggregator and the battery provider did not enable the resolution of this software issue within the timeline of the project. As a result, it was not possible, as part of this project, to either prove or disprove the capability of the battery systems to provide voltage support to the network.

Lower Power Factor leads to increased losses on the network, leading to reduced capacitance on the transformer. Maintaining a Power Factor of unity (1) or close to it would limit such losses, however the inability to carry out such tests over a prolonged period, meant that it was not possible to prove this as part of the StoreNet project.

Lessons have been learned by all project partners, on the importance of a robust software maintenance agreement being in place to underpin projects of this nature.

DS3 Event February 2020

As part of DS3 (EirGrid programme to deliver a secure, sustainable electricity system) testing performed by the VPP Aggregator during February 2020 (outside the scope of the StoreNet project, albeit using the same VPP), most of the 20 battery systems exported to the grid for a 20-minute period. Over this time period the observed Power Factor (PF) went to 1.

Peak Lopping / Peak Shaving

To test peak lopping/peak shaving a number of tests were designed and executed over the 4-day period, 17th to 20th November 2020 as follows:

- Day 1 – operate the batteries such that there is no discharge into participants' homes or onto the network over the hours 16:00 to 20:00 – establish baseline;
- Day 2 – fully discharge the batteries over a 4-hour period 16:00 to 20:00. Power output will be ~2.3 kW;
- Day 3 – fully discharge the batteries over a 3-hour period 16:00 to 19:00. Power output will be 3.3 kW;
- Day 4 - operate the batteries such that there is no discharge into participants' homes or onto the network over the hours 16:00 to 20:00;

FIGURE 5 – VPP OBSERVATIONS: PLOTTED THE PEAK PERIOD EACH EVENING (16:00-20:00)

GREEN LINE – MAIN INCOMER MEASUREMENTS

YELLOW LINE – BATTERY POWER

From a VPP Aggregator perspective all batteries performed as expected during these tests. Note that it is not uncommon for a battery to stop charging or discharging for a short period of time, however the VPP Aggregator implemented a 5-minute decision period within its software for these systems, so battery deactivation didn't extend beyond that (unless the battery was offline). In the image above, the observed switch from discharging to charging by the batteries on Day 2 and Day 3 resulted from the 10% minimum state of charge (SOC) hardcoded for each battery within the VPP. As the VPP Aggregator discharged the batteries towards zero during these tests, the SOC minimum applied and the batteries started automatically charging to achieve the 10% state of charge.

For information, Site Power (Green Line) is what is measured at main incomer with negative readings indicating import and positive values indicating export. Battery Power (Yellow Line) is active power at the inverter. Negative in this case indicates that the battery is charging while positive values indicate discharge.

It can be observed – Figure 6 below - (as expected) that the voltage profile slightly improves with the batteries discharging power to the grid on 25th and 26th (Days 2 and 3) over the evening peak, compared to Day 1 and Day 4 of this test. Consumer demand is removed from the network as the batteries discharge.

The distribution network is designed to meet the peak demand on that part of the network. As such, there may be opportunity to design the network in particular locations, to a reduced peak, at a reduced cost if a reliable service is available e.g. battery storage systems to provide this differential between max demand and designed demand. However, in advance of any local implementation, detailed analysis by ESB Networks would be required to determine whether this is an enduring viable solution.

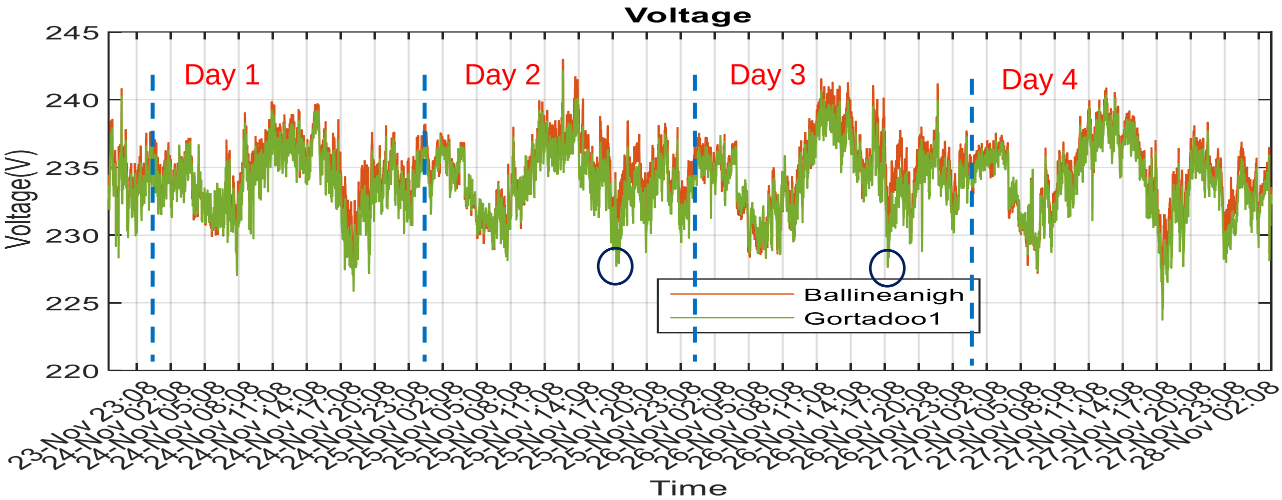

FIGURE 6 - LV VISION DEVICE DATA AT THOSE TRANSFORMERS WHERE ONLY ONE CUSTOMER CONNECTED

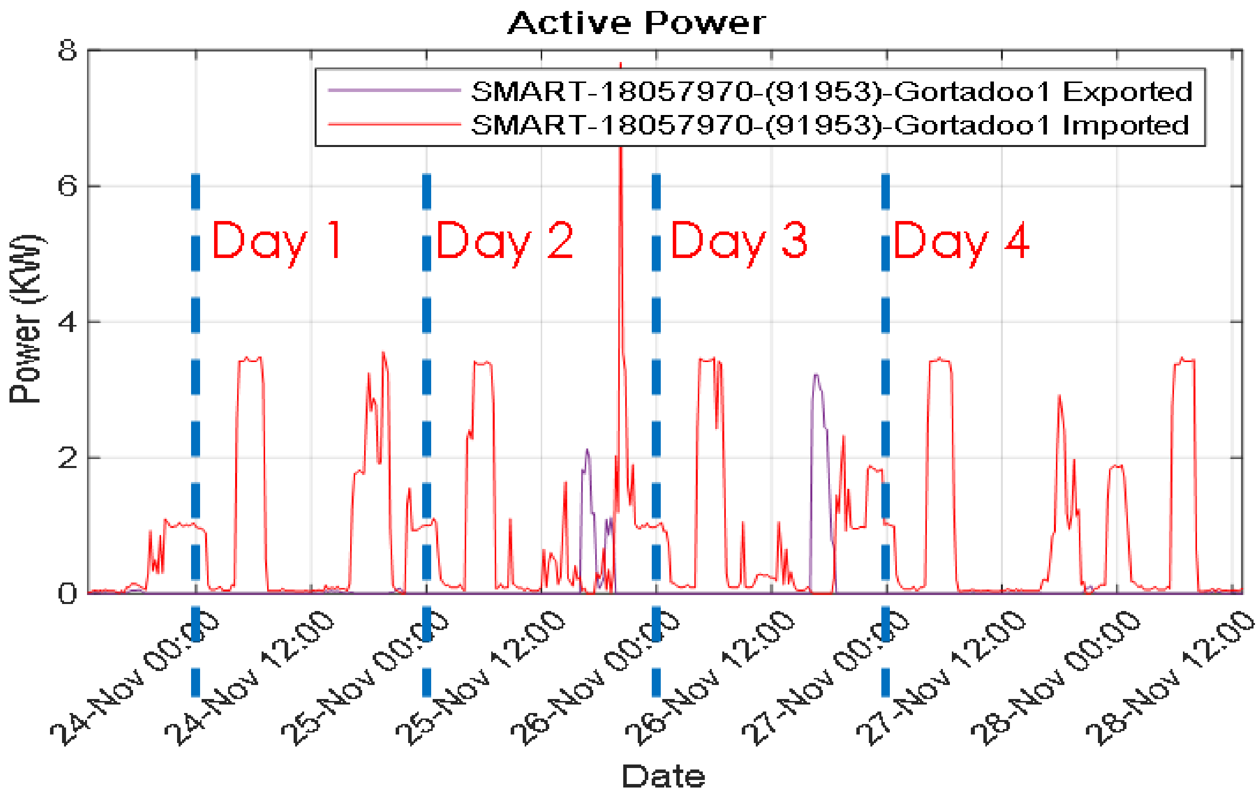

FIGURE 7 - GORTADOO1 METER DATA (ONE CUSTOMER CONNECTED AT THIS TRANSFORMER)

Figure 7 shows the metered data (import and export) for the only customer connected to Gortadoo1 LV/MV transformer. This graph clearly shows that there is no second demand peak in the evenings (Days 2 and 3) when the battery was discharging in this premises, when compared against Days 1 and 4 when the battery was not discharging at evening peak.

Days 2 and 3 also show that customer demand did not exceed the provided power from the battery and hence we see some power exported back onto the network.

IERC Monitoring and General Observations

There are 18 LV Vision Devices installed across the network at Ballyferriter. The measured quantities on these devices are active power, apparent power, current, frequency, harmonic content, power factor, reactive power, Current THD, Voltage THD, and voltage. All the lines display the same voltage behaviour (i.e. voltage drops around 7 AM and 6 PM – which corresponds to morning and evening peak periods for power consumption), with the severity of the voltage drop depending on the absorbed power. The higher the absorbed power is, the higher the voltage drops.

Studying the behaviour of different voltage, current, active power, and reactive power profiles, it was observed that charging the batteries corresponds to a slight drop in the voltage (as the connected load increases). Projecting into the future, such voltage drops will increase in magnitude should the number of batteries deployed and battery capacity increase, albeit developments in battery controls may potentially offer a way to control such drops.

IERC is also of the view that installation of batteries on one phase of a three-phase network will alter the phase balance, albeit that these batteries can be controlled to help balance these phases. This is an area of study that requires further focus.

In order to consolidate observations, IERC recommends that the following would be required:

- Remote read interval meter data from other points on the network
- Sensor and instantaneous measured data at some MV network points
- A longer timeframe (minimum 1 year) with good quality data in the same time frame and interval to understand the impacts further.
- The establishment of a baseline of data for 12 months prior to testing, as the lack of such baseline means that the impact of the batteries and their operation is difficult to understand.

4. LEARNINGS AND RECOMMENDATIONS

Peak Shaving

From a technical perspective, battery systems can be operated in a manner so as to support peak shaving. However, the small scale (3.1A at MV for 287A at LV for full discharge of 20 batteries with a 3.3kWp inverter) of the power output in the peak shaving tests and the distributed nature of this battery output, reflecting the distributed locations of trial participants across the network at Ballyferriter, means that for any substantial benefits to be realised by ESB Networks, services would need to be procured on a much larger scale and / or in a more clustered / concentrated location on the network.

Reactive Power Support

The StoreNet tests were inconclusive due to software issues experienced during the trials. The version of the battery system provider’s software API procured by the VPP Aggregator, for the purposes of the StoreNet Project, did not support the required testing and it was not possible for this to be corrected within the term of the project.

It should be noted that the Horizon 2020 RESERVE project, of which ESB Networks was the field trial leader, demonstrated that inverters can be controlled to enable reactive power support albeit that there may be challenges identifying productized battery system configurations that are suitable for residential setting installations.

Valuable lessons have been learned by all project partners, on the importance of a robust software maintenance agreement being in place to underpin projects of this nature.

Total Harmonic Distortion (THD)

There is quite a volume of IERC report content pertaining to THD and its impact on the network. In summary an increase in THD caused by DER may degrade the network over time and it needs to be monitored. The LV Vision devices installed on the network as part of the StoreNet project enable the measurement of THD.

For further information on the LV Vision devices, see the Winterpeak Project closedown report.

Ownership of Battery Systems

Regulations will prevent ESB Networks from owning or directly controlling the operation of batteries on the network in the future. As such, should the provision of network support through controlled operation of battery systems prove technically and commercially viable, any such network services would require to be procured by the DSO from the market.

Improvement to customer recruitment techniques

An ideal outcome for ESB Networks from the trial participant recruitment activity would have been for all consumers, connected to particular MV/LV transformers, to participate on the project's trials. This would have facilitated the performance of local load balancing tests. However, in Ireland's competitive retail electricity market, consumers are free to contract with the electricity supplier of their choice and since recruitment of trial participants for the StoreNet Project was managed by the Electricity Supplier partner on this project, its recruitment activities were naturally focused on its existing customer base in that area.

In addition, as the trial required the installation of battery technologies behind-the-meter at customers' premises, it was necessary to canvass customers in the locality and seek their agreement to participate. Recruitment was aided considerably through the support of the Dingle Innovation and Creativity Hub, but nevertheless resulted, for ESB Networks purposes, in a less than ideal distribution of batteries to consumers across the Ballyferriter area, with no significant clustering of battery technology on the network as a result.

Leveraging local (community based) advocacy initiatives may build trust and encourage targeted consumers to participate in trials, however, where electricity Supplier contractual relationships with customers must also be maintained, this may complicate trial recruitment outcomes particularly where project objectives differ across multiple project partners.

For any future ESB Networks led trials, increased efforts should be made to ensure targeted recruitment of customers with primary project objectives and desired outcomes in mind.

Diffusion of Active Energy Citizen Behaviours across the VPP Community

As part of the StoreNet project, the Electricity Supplier partner installed Solar PV at five of the trial participant residences. These installations were designed and configured to help demonstrate the technical performance and commercial value propositions of integrated Solar PV and battery systems.

Based on the experience and learnings shared among trial participants, some additional StoreNet participants funded their own purchase of Solar PV so that they could maximise its potential when operated in conjunction with the battery systems. This example shows that diffusion of active energy citizen behaviours can be enabled through the sharing of experiences across communities and highlights the benefit of designing project communication strategies to enable such outcomes.

LV Vision Devices – Data Gaps

The LV Vision Devices were installed in advance of the winter peak in December 2019. It was anticipated that there would be 12 months data from the 18 devices installed for the project purposes. However, upon later retrieval of data, for analysis purposes, it came to light that there were instances of significant gaps in monitoring data. A recommendation from the project would be to implement an automatic notification system for missing data, such that events such as communications interruptions could be highlighted early in order to minimise data loss.

Deferral of Investment Opportunity

The suite of tests in November demonstrated that – provided such systems are controllable (whether by a VPP Aggregator or other party) under the terms of a technically and commercially viable services contract with the DSO - there may be potential for battery systems to (a) reduce consumer demand at the peak demand time by discharging at this time and (b) shave the peak by exporting unused battery capacity to the grid at peak demand times.

As stated previously, reducing the peak demand could allow that area on the network to be designed to cater for a lower peak and hence be constructed at a lower cost. It may also be inferred that if a large number of customers on a substation have battery systems, then design and control of the batteries as a VPP could thereby allow for additional customers to be connected to the same substation (transformer) without upgrading the transformer. Due to the scattered distribution of the StoreNet participants and the relatively small output capacity of each battery, the actual impact of the VPP was negligible on the MV Network but certainly displayed potential as outlined in the IERC report available through its website (www.ierc.ie).

5. FINAL TIMELINES

The key milestones of the project, relevant to ESB Networks were as follows:

- Meter Installation – Sep 2019;
- LV Vision Device installation – Dec 2019;
- Active Power Management tests – April 2020;
- Peak Shaving / Lopping tests – Nov 2020;
- Final consortium meeting – Mar 2021;
- Final ESBN Report – June 2021;

6. FINAL COSTS

Costs, excluding ESB Networks' project team costs, incurred by ESB Networks for the StoreNet Project were €230k and were composed of the following items:

- MAC LV vision devices and installation;
- Remote-read interval metering back-end system and software maintenance;

- Contribution to cost of battery systems;

7. NEXT STEPS – TRANSITION OF LEARNINGS

ESB Networks has held a number of workshops and meetings with the StoreNet partners to disseminate the learnings throughout the project. The project team have held a series of internal workshops and presentations to disseminate the project learnings to the relevant ESB Networks business units.

If you would like further information/data from this project, please contact us at innovationfeedback@esbnetworks.ie