European Commission | Horizon 2020 European Union funding for Research & Innovation

Operation and integration considerations for distinct Qualifier trial providing units of system services.

4.6

EU-SysFlex

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.

PROGRAMME	H2020 COMPETITIVE LOW CARBON ENERGY 2017-2-SMART-GRIDS
GRANT AGREEMENT NUMBER	773505
PROJECT ACRONYM	EU-SYSFLEX
DOCUMENT	4.6
TYPE (DISTRIBUTION LEVEL)	☒ Public ☐ Confidential ☐ Restricted
DUE DELIVERY DATE	30/11/2021
DATE OF DELIVERY	
STATUS AND VERSION	V0.2
NUMBER OF PAGES	75
Work Package / TASK RELATED	WP4 / Task 4.3
Work Package / TASK RESPONSIBLE	John Wallace (EirGrid) / Daniel Dixon (EirGrid)
AUTHOR (S)	Daniel Dixon (EirGrid)

DOCUMENT APPROVERS

PARTNER	**APPROVER**
EirGrid, EDF	John Wallace (WP Leader) and Marie-Ann Evans (Technical Manager)
EirGrid	John Lowry (Project Coordinator)

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

EU-SYSFLEX	Pan-European System with an efficient coordinated use of flexibilities for the integration of a large share of Renewable Energy Sources (RES)
DS3	Delivering a Secure Sustainable System
DSM	Demand Side Management
DSO	Distribution System Operator
DSR	Demand Side Response
DTS	Dispatcher Training Simulator
EED	Energy Efficiency Directive
EV	Electric Vehicles
GSM	Global System for Mobile Communications
NC	Nodal Controller
POAS	Power Off and Save
POR	Primary Operating Reserve
PV	Photovoltaic
QTP	Qualification Trial Process
RTU	Remote Terminal Unit
PPM	Power Park Module
SMS	Short Message Service
SOR	Secondary Operating Reserve
SNSP	System Non-Synchronous Penetration
SPAYG	Smart Pay As You Go
SSRP	Steady State Reactive Power
TOR	Tertiary Operating Reserve
TSO	Transmission System Operator
WFPS	Wind Farm Power Station
WP	Work Package

EXECUTIVE SUMMARY

This report presents the learnings and the outcomes of activities carried out under the EU-SysFlex Qualification Trial Process (QTP) in Ireland and Northern Ireland, T4.3 of the H2020 EU-SysFlex project. Building on the 2017/2018 trials, the 2019/2020 trials focussed on Solar, Residential Services and enhanced communication protocols for new and existing technology. Following a successful procurement in 2019, the TSOs conducted three new trials focussing on proving technology, measurability and capability in embedded technology. Table 1 below outlines the industry partners that were part of the successful tender application for the 2019/2020 trials.

Trial	Trialists
Lot 1 - Solar	Bann Road Solar (Green Coat Capital)
Lot 2 – Residential Services	Energia
	SMS formerly Solo Energy
Lot 4 – Telecommunications	Energia
	VIOTAS formerly Electricity Exchange

TABLE 1

Each of the trials has demonstrated valuable learnings to the TSO. Firstly, the solar trial has shown that solar photovoltaic technology can deliver system services of FFR, POR, SOR and TOR1. In addition, the trials have identified operational complexities associated with solar technology. These primarily relate to the ability to provide reactive power at night, forecasting of response and testing of units to demonstrate capability.

Two participants were successful on the residential trials: Energia and SMS (previously Solo Energy). Both participants implemented a different methodology and range of technologies as part of the trial demonstration of System Services capability. Each trial successfully demonstrated that a subset of system services is possible from the technologies in domestic properties. Each trial delivered an aggregated response for SOR, TOR1 and TOR2. Currently, FFR and a complete POR response seem unlikely unless frequency meters are located onsite with upgrades required in the metering hardware to allow for millisecond monitoring, measurement, and validation. It is a finding of the trials, that fast-acting services could be achieved by allowing more suitable, cost-effective frequency meters and metering requirements to be used to avoid a significant negative impact on the cost to manufacture and install the required technologies.

Since these trials commenced, battery technology manufactures have developed faster-responding solutions, which could be used in future demonstrations to deliver the full suite of system services. However, more significant research and knowledge are required in the area. The trials locations were geographically dispersed participants across Ireland, so they did not assess the impact of residential services providers at scale. Therefore, the SO's further need to understand the implications and the complex interactions of residential demand-side management.

Finally, the report discusses the learnings and outcomes of the telecommunications protocol trials. In total, two trials took place, focussing on alternative forms of communication protocols. Both Energia and VIOTAS brought forward new solution designs that have helped the TSO's look at telecommunications possibilities. The learnings and outcomes have identified several operational complexities for integrating alternative telecommunications protocols. This primarily focuses on security, protocol-based communications, standardised end to end telecommunications and communications to control centres. The key findings from the trials will help develop a roadmap for telecommunications between the distributed energy resource (DER) and the TSO's in the future. With the help of the trials, the TSO's have developed a clearer understanding of suitable solutions available and how they could be implemented. These findings will help steer our course towards a more efficient telecommunications network. While security concerns are still a significant challenge for TSO's worldwide, it is fully understood that this work needs to be carried out in collaboration with our security partners and the broader industry to help deliver suitable solutions.

The following sections of the report provides a detailed overview Work package 4, the Qualification Trial Process, (QTP), each trial and the individual learning and outcomes. Every trial is presented in a manner that permits individual reading for each. The background to each trial, project objectives, learning, and outcomes are presented for each trial. Section 5 of the report presents the Solar Trial. Section 6 presents the SMS and Energia trials for residential services. Finally, Section 9 outlines the communication trials. It should be noted the learning and outcomes discussed in the report are those of the trial participants and will be considered in the future by the TSO.

1. INTRODUCTION

WORK PACKAGE 4

The EU-SysFlex project seeks to enable the European power system to utilise efficient, coordinated flexibilities in order to integrate high levels of renewable energy sources. One of the primary goals of the project is to examine the European power system with at least 50% of electricity coming from renewable energy sources (RES-E).

In order to reach at least 50% RES-E on a European scale, it will be necessary to integrate very high levels of variable non-synchronous renewable technologies such as wind and solar. Transitioning from a power system which has traditionally been dominated by large synchronous generating units to a system with high levels of variable non-synchronous renewable technologies has demonstrated complex system operational challenges in providing the necessary system resilience and reliability. This is due to the non-synchronous nature of these technologies as well as the variable and uncertain nature of the underlying resources.

The integration of non-synchronous renewable generation results in the displacement of synchronous generators; this can consequently lead to technical scarcities in power systems. In order to address these scarcities, it will be necessary for new and existing technologies to provide flexible system services. In this regard, Work Package 4 (WP4) acts as a gateway, providing the technical platform to trial these services and technologies and provides a route to an enduring market. WP4 will also develop the system operator decision support tools required to operate the system in a secure manner with a high penetration of RES-E and system services. WP4 will also assess the system operator training needs for operating a system with a high penetration of RES-E and system services through a Dispatcher Training Simulator (DTS) of a significant part of the EU network.

WP4 interacts with other WPs within the EU-SysFlex project; the project structure can be seen in Figure 1. WP2 will identify the system scarcities associated with operating the system at high levels of renewables. In WP3 products will be designed to meet the needs of the scarcities identified in WP2. The decision support tool developed in T4.1 will use the services identified in WP3. The DTS in T4.2 will model a subset of the services identified in WP3 and will be based on the scenarios identified in WP2. The Qualification Trial Process in T4.3 will trial new and innovative technologies wishing to prove capability to provide system services and T4.4 will develop the operator protocols required for specific system and market conditions. This will act as a key input into the flexibility roadmap developed in WP10.

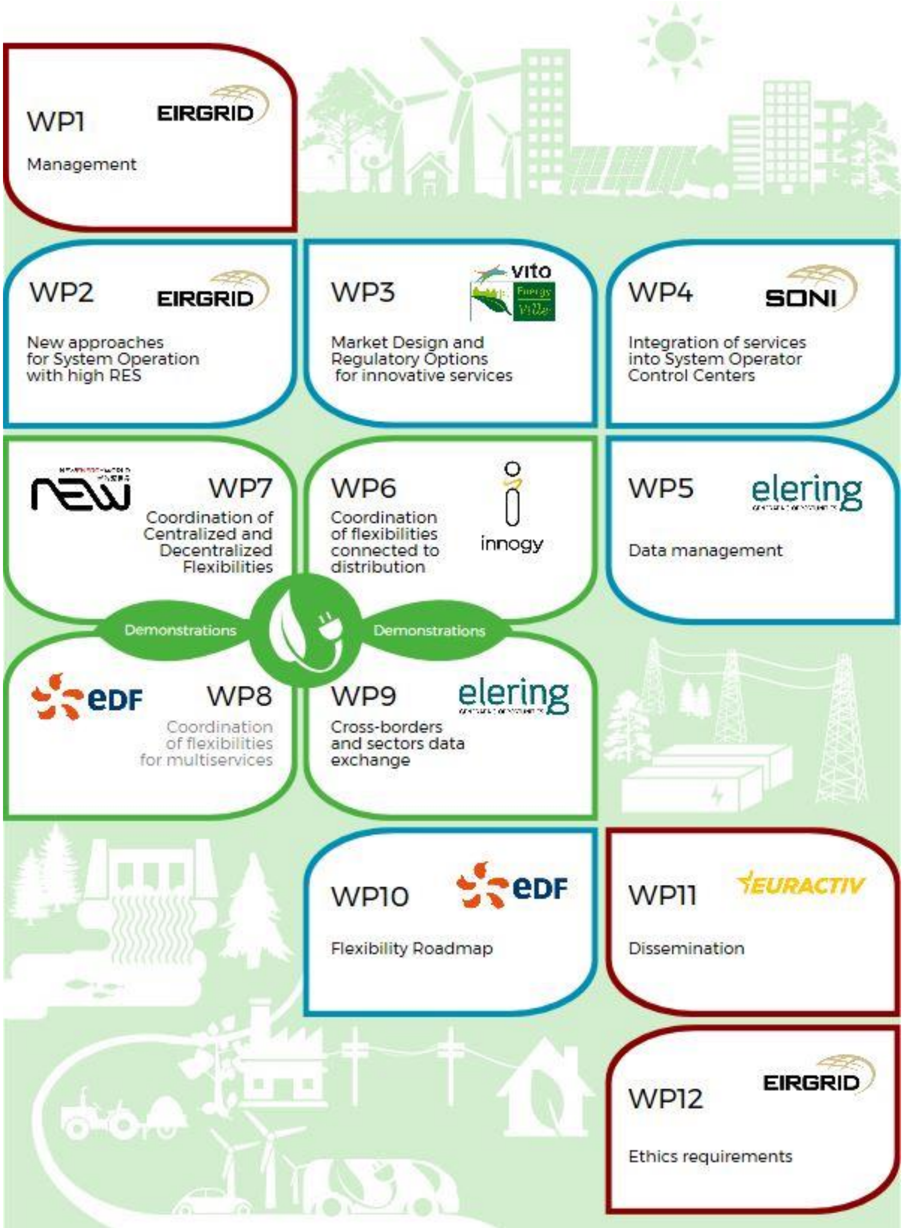


FIGURE 1- EU-SYSFLEX WORK PLAN

T4.3 WITHIN SYSFLEX

The Qualification Trial Process (QTP) in T4.3 provides the technical platform to trial resilience services from new technology providers and provides a route to an enduring services market. The QTP provides the link that facilitates the transition from fossil fuel tradition, to a sustainable renewable power system. It is a central piece of a much broader programme of work led by the EirGrid and SONI to meet the objectives of 70% electricity from renewables in Ireland and Northern Ireland by 2030. Today, Ireland & Northern Irelands' power system is the first in the world capable of delivering 70% of instantaneous electricity demand from non-synchronous sources including wind and solar.

MAIN CHALLENGES LINKED TO HIGH RES-E PENETRATION

In seeking to meet Ireland and Northern Irelands renewable objectives of 2030, the power system needs to be capable of operating at up to three quarters of the power being delivered from non-synchronous renewable technologies. As the current operational limit of 70% is increased to 75% (currently being trialled), reliance on new technologies to provide the resilience of the system will increase. Today, Ireland and Northern Ireland are addressing the challenges that Europe will likely see in the future. As Europe aims to achieve over 30% of its overall electricity needs from new renewable sources by 2030, this poses challenges to traditional system operation and new technology integration;

- How should a power system transition in order to obtain or procure these resilience services from new technologies when no one else in the world is seeing these issues?
- How will this transition succeed without threatening the security of the power system?
- How can a route to market be created to facilitate investment in demonstrations to satisfy technical scarcities?
- Can this be done in a way that links the commercial, technical and system integration aspects of not the one or the few, but the large-scale deployment of these new technologies?

T4.3 will facilitate the real-time technology trials of new technologies for relevant system service provision on the Ireland and Northern Ireland power system. This will help to identify and to resolve operational protocols, technology capability and communication challenges and work with industry through a technology integration forum to address further system integration challenges. More generally, the trials will also consider the challenges associated with the large scale roll out of these new technologies. The output of this task is the appropriate solutions on operational protocols, dispatch tools and scheduling processes to qualify the new technology for system service provision on a large scale in the Ireland and Northern Ireland system in a prudent manner.

2. MANAGAGING THE TRANSITION TO NEW TECHNOLOGIES

Over the past ten years, the Transmission System Operators in Ireland and Northern Ireland have seen increasing changes in the technology that makes up our electric power system. Behind-the-meter technologies such as rooftop solar PV, Battery Storage, Vehicle to Grid Charging and energy management systems is changing the power system. The need for greater transparency of data and information will also drive change across the sector. As renewable generation (predominantly wind & solar in Ireland and Northern Ireland), displaces conventional generation on the system, these new technologies must also provide System Services to maintain resilience.

A transition to a power system with high levels of non-synchronous generation will result in new system scarcities. These scarcities are due to traditional providers of services (such as conventional generation) being displaced at times of high levels of non-synchronous generation. This drives the need for system services from an enhanced portfolio of service providers, consisting of a mixture of the existing services provider and new service providers with enhanced capabilities and new technologies.

A level of confidence and understanding of existing service providers' technologies has been built up through years of operating the power system with increasing reliance on these technologies. Confidence has been developed through operational practice, learnings and continual improvement. EirGrid and SONI also have well established policies, tools and systems in order to schedule, operate, remunerate and monitor the performance of these service providers. However, many new technologies fundamentally challenge these existing processes and operational confidence. Therefore, the transition to an enhanced portfolio of services provider needs to be managed in a prudent manner, allowing the TSOs time to study and assess their impacts. This helps to ensure that outcome of an enhanced portfolio of services provider, whilst also ensuring the system is managed in a secure, reliable and efficient manner.

3. THE QUALIFICATION TRIAL PROCESS

The QTP is the mechanism through which the TSOs in Ireland and Northern Ireland are managing the transition to a wider portfolio of system service providers. The aim is to identify operational complexities that may be associated with new technologies, or delivery of new System Services. In doing so, the EirGrid and SONI can develop a deep understanding of these complexities and suggest solutions on how to best integrate these technologies at scale on the power system on the Island of Ireland and Europe. The trial process is depicted below in Figure 2 – Visualisation of how QTP facilitates changes in system operation.

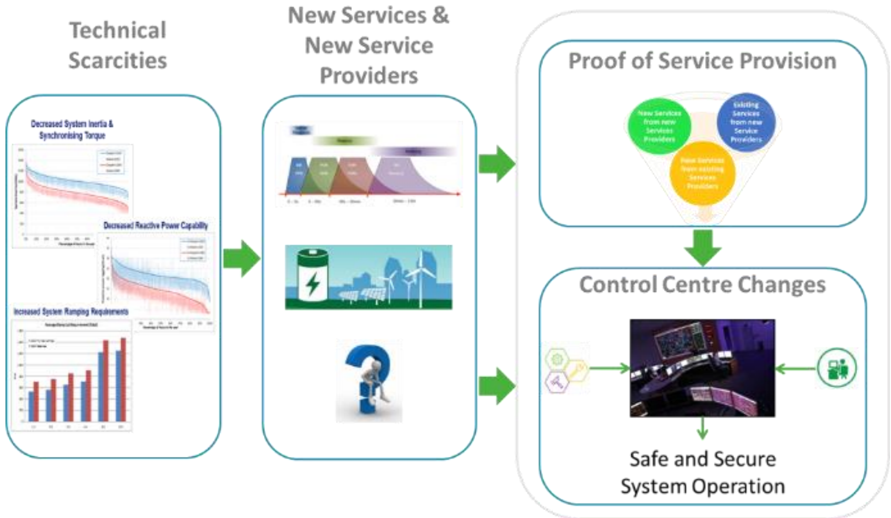


FIGURE 2 – VISUALISATION OF HOW QTP FACILITATES CHANGES IN SYSTEM OPERATION

TRIAL PRINCIPLES

There are several key principles which underpin the QTP:

1. The trials are run at small scale allowing participants to demonstrate provision of system services in small volumes. This demonstrates provision of services under real system operational conditions, but the small-scale nature of the trials also ensures security of the power system.
2. Outcomes of a technology trial will inform whether the EirGrid and SONI consider a technology's ability to provide several system services within a service category as proven. An example of this is that a successful participation in a primary operating reserve trial may be considered as proof of the capability to also provide secondary.
3. The trials will inform whether the TSOs consider the capabilities of a technology class or sub-class as proven to provide a system service, and not a specific service provider or original equipment manufacturers. An example of this is that if a wind farm has been deemed to be proven under the wind category of trial for a service, this means that wind as a technology class has been deemed to be proven.
4. The failure of specific participant in the QTP does not necessarily exclude its technology class from provision of the service forever. Depending on the reasoning for the failure of a trial, EirGrid and SONI may elect to run a future trial with a separate service provider or alternatively consider other ways that may inform whether the TSOs consider the capabilities of a technology class or sub-class as proven.
5. Successful participation in a QTP does not guarantee that a service provider will obtain a contract in the main procurement process. This will be subject to the technical requirements set out as part of the procurement process.

THE TWO CORE OBJECTIVES:

1. To identify if the participants technologies could provide a response to an event in line with the definition of the System Service(s) being demonstrated and
2. To identify any operational complexities driven by the provision of services System Services from these technologies and provide suggestions on how to approach or resolve them.

Objective 1 is considered a minimum requirement for a technology class to be considered as proven for the provision of relevant system services through the QTP. To achieve this objective, participants were required to demonstrate responses to real system events that occurred during the trial period, in line with the System Services definitions.

Objective 2 requires more careful consideration of how each technology provided the service being trialled and what impacts they had on current EirGrid and SONI processes and systems. The outputs of objective 2 will inform the development of TSO standards and processes to manage system services from different technologies.

4. DS3 SYSTEM SERVICE PRODUCTS – IRELAND AND NORTHERN IRELAND

New technologies seeking to demonstrate service provision and thereby fulfil the objectives set out above must show responses to system conditions and/or test injections which satisfy the local System Services definitions in Ireland and Northern Ireland. These are:

FAST FREQUENCY RESPONSE

Fast Frequency Response (FFR) is the additional MW output or MW reduction required compared to the pre-incident MW output or MW reduction, which is fully available from a providing unit within 2 seconds after the start of an event and sustainable up to 10 seconds after the start of the event. The extra energy provided in the 2 to 10 second timeframe must be greater than any loss of energy in the 10 to 20 second timeframe due to a reduction in MW output or MW reduction below the pre-incident MW output or MW reduction.

RESERVE

Primary Operating Reserve (POR) is the additional MW output and/or reduction in demand) required at the frequency nadir (minimum), compared to the pre-incident output (or demand) where the nadir occurs between 5 and 15 seconds after an event. If the actual frequency nadir is before 5 seconds or after 15 seconds after the event, then for the purpose of POR monitoring the nadir is deemed to be the lowest frequency which did occur between 5 and 15 seconds after the event.

Secondary Operating Reserve (SOR) is the additional MW output and/or reduction in demand) required compared to the pre-incident output (or demand), which is fully available and sustainable over the period from 15 to 90 seconds following an event.

Tertiary Operating Reserve 1 (TOR1) is the additional MW output and/or reduction in demand) required compared to the pre-incident output (or demand) which is fully available and sustainable over the period from 90 seconds to 5 minutes following an event.

2019 QUALIFICATION TRIAL PROCESS (QTP)

Following the completion of the QTP in 2017 and 2018, EirGrid and SONI applied several of the learnings based on the feedback from trial participants. As a result, the TSOs expanded the scope of the QTP to incorporate a wider range of topics. The purpose for this is to develop a centralised workstream to identify commercial and technical considerations for the large-scale deployment of new technologies on the power system for 2030. In 2019, three projects were selected to examine these barriers. The trials focus on three technical considerations, network, and communication and future barriers.

Trial 1 – Solar photovoltaic (PV) generation has become a more economically viable form of electricity generation in Ireland and Northern Ireland in recent years. It is likely that large scale solar PV will connect to the system at an increasing rate from the mid-2020s without the need for a subsidy due to decreasing capital costs. Wind and solar are anticipated to become the dominant renewable technologies on the system that will aid Ireland and Northern Ireland achieving its net zero targets for 2050.

Trial 2 – Residential Service Providers - EirGrid and SONI are now investigating the operational complexities associated with automated response from in-home technology. The objective is to investigate the potential of- and challenges involved in leveraging the flexible capability of the residential sector to provide System Services in the future. The TSOs envisage real benefits from DSM in reducing peak demands to the power system and the provision of essential System Services and recognise the importance of Demand Side Management to the delivery of energy efficiency targets. The system operators will use the project to investigate the potential delivery of wide-scale residential DSM which has benefits in assisting Ireland to reach its renewable energy targets by providing greater flexibility in operating the power system with up to 70% renewable generation, which will require the ability to operate the power system with as much as 95% of generation from renewables at times.

Trial 3 – Communication - Due to the increasing use of renewable energy sources, TSOs worldwide are seeing a shift from operating a centralised portfolio of large conventional fossil-fuel generators to a more widely distributed network which includes small-scale generation. The current communication method was designed for larger generators, which has resulted in a communication solution that may be inflexible or expensive for small scale generation or other service providers on the system such an aggregator. This project enables a two-way communication between a small-scale service provider or aggregator and the system operator.

The following sections of the report provide a detailed overview of each trial and the individual learning and outcomes. Every trial is presented in a manner that permits individual reading for each. The background to each trial, project objectives, learning, and outcomes are presented for each trial. Section 5 of the report presents the Solar Trial. Section 7 & 8 presents the SMS and Energia trials for residential services. Finally, Section 9 outlines the communication trials

5. SOLAR TRIAL

This section of the report details the works that Bann Road Solar Project Ltd. (Bann Road) has undertaken as part of the Qualification Trial Process. The report details how solar technology can provide the DS3 services of FFR, POR, SOR, TOR 1 and SSRP. The report details how the solar farm performed during the trial and what lessons can be learned for future trials.

TRIAL OBJECTIVE

The overall objective is to prove solar technology capable of providing a range of the DS3 System Service products - FFR, POR, SOR, TOR1, under the QTP and identify any operational complexities. During the provenability trial, EirGrid and SONI monitored the provision of the Services in response to real events on the power systems of Ireland and Northern Ireland or the response to dispatch instructions issued to the Providing Unit. Service provision or testing was conducted as per the current DS3 test procedures to measure the capability.

DEMONSTRATION OF SERVICES.

The Fast acting services of FFR, POR, SOR and TOR 1 involve the delivery of additional power to the grid during a dip in Frequency. Bann Road can demonstrate the Fast Acting Services of FFR, POR, SOR, and TOR 1. Certain wind turbine technologies can provide FFR and POR via a product known as "Emulated Inertia". However, as there are no moving parts in the solar project the provision of Emulated Inertia is not possible. The Services of FFR, POR, SOR and TOR 1 may only be demonstrated when the Solar farm is curtailed. Table 1 provides details on the four fast acting services that were tested during the trial.

Service Name	Acronym	Short Description
Fast Frequency Response	FFR	MW delivered between 2 and 10 seconds in response to automated frequency trigger
Primary Operating Reserve	POR	MW delivered between 5 and 15 seconds in response to automated frequency trigger
Secondary Operating Reserve	SOR	MW delivered between 15 to 90 seconds in response to automated frequency trigger
Tertiary Operating Reserve 1	TOR 1	MW delivered between 90 seconds to 5 minutes in response to automated frequency trigger

TABLE 1. DESCRIPTION OF FAST ACTIVE SERVICES

5.1.1 FAST ACTING SERVICES MONITORING EQUIPMENT

The power quality meter originally installed on site did not meet the requirements detailed in "DS3-Performance-Measurement-Device-Standards-for-Fast-Acting-Services". Immediately after the commencement of the trial a meter was procured and installed on site. An "EMSni Subnet" meter was connected to the CTs and VT at the connection point. Three additional analogue signals were also connected to the meter to facilitate the remote testing of the site.

- MW Availability (Available Active Power)
- % MW Curtailment Setpoint
- Frequency Simulated Value

5.1.2 FFR, POR, SOR AND TOR

The Solar Farm can only provide under frequency response when the solar farm is curtailed. SONI can curtail the Solar farm by using one of two curtailment methods

- Emergency Action ON
- % MW Curtailment

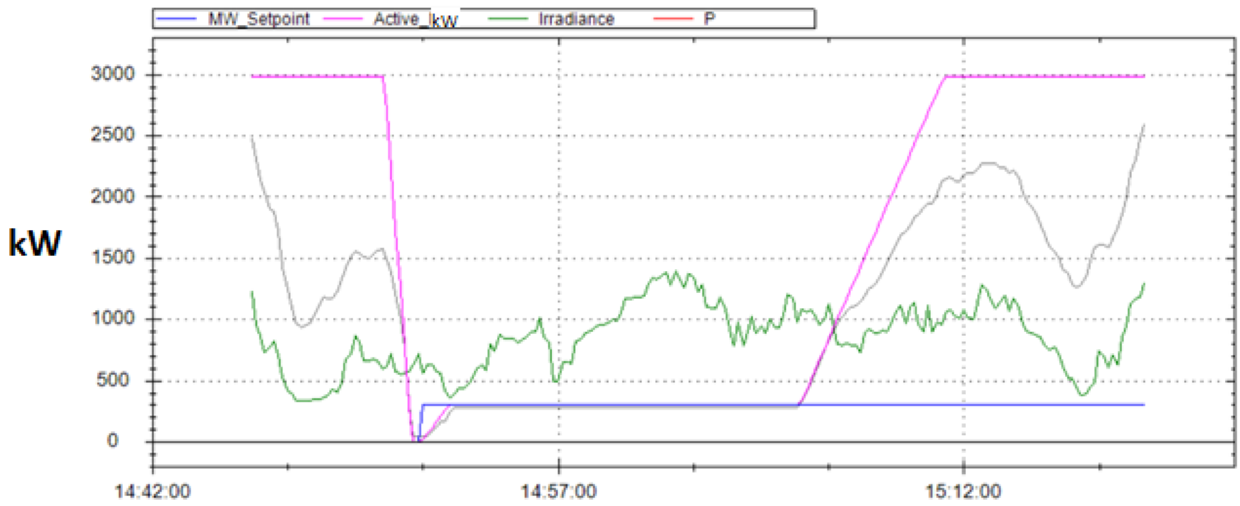


FIGURE 13. EMERGENCY ACTION ON CURTAILMENT

5.1.3 EMERGENCY ACTION ON CURTAILMENT.

To curtail the Solar farm using Emergency action on SONI send a MW setpoint to the Solar Farm controller along with a time setting known as "Curtailment Time Interval". The curtailment time interval signal determines how fast the Solar farm ramps to the MW setpoint. Figure 1 shows the solar farm initially ramping down to a setpoint of 0 MW and then up to a setpoint of 250KW. Not shown in the graph is where SONI/ NIE would have turned Emergency Action Curtailment on and off. It can be assumed that emergency action on was enabled when the output of the solar farm decreased to 0MW (approx. 14:52). It can also be assumed that emergency action on was disabled when the solar farm ramped up from 250 kW (approx. 15:07). Currently renewable generation units connected in Northern Ireland are not required to provide under frequency response when curtailed using emergency Action ON. As this type of curtailment is used in renewable generation connected in Ireland, a modification was made to the solar farm controller to enable it to demonstrate under frequency response when curtailed by "Emergency Action ON".

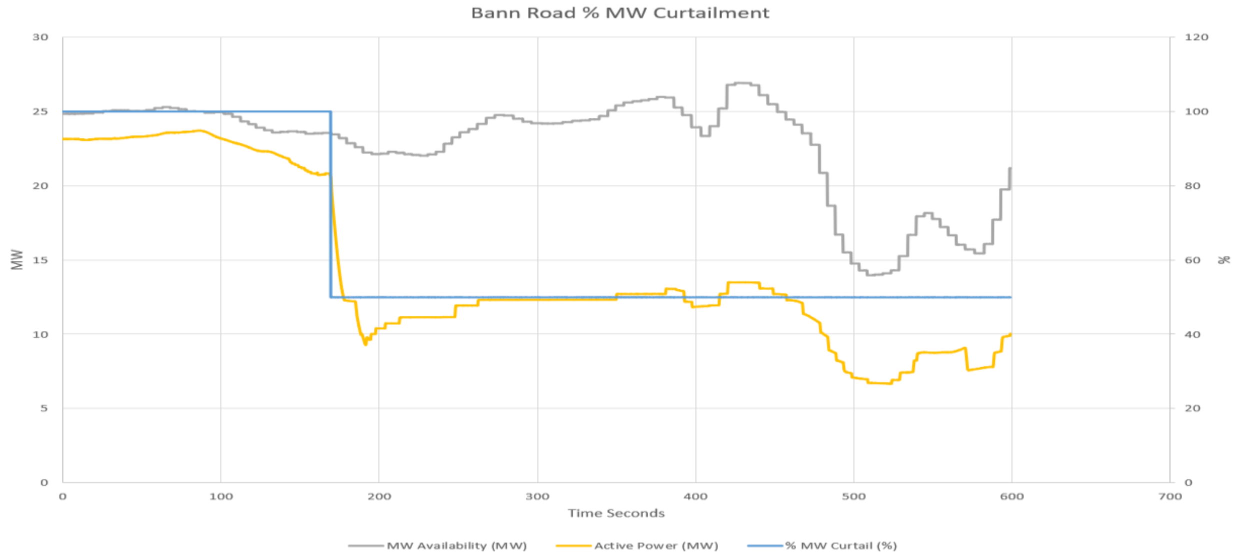


FIGURE 2. % MW CURTAILMENT

To Curtail the solar farm using % MW curtailment SONI issue a setpoint from 0% to 100%. In the example given in Figure 2 a 50% MW curtailment setpoint was issued. The output of the solar farm then ramps down to an output of 50% of its MW Availability (Available active power). The output of the solar farm is constantly adjusted so that 50% of MW availability is maintained while % MW Curtailment is activated.

The frequency response characteristics of Bann Road are currently set up in accordance with the SONI/ NIE Grid code. The Solar farm operates to a deadband of 50Hz to 50.1Hz when % MW Curtailment is not enabled and a deadband of 49.985Hz to 50.015 Hz when % MW Curtailment is on. The solar farm will provide under frequency response when in % MW curtailment mode.

5.1.4 OPERATING RESERVE TEST % MW CURTAILMENT

To demonstrate Bann Roads capability to provide the fast-acting services of FFR, POR, SOR and TOR 1 while curtailed using % MW curtailment an operating reserve test was performed. The test procedure that was used to define the test parameters was the exact same template that is used for the operating reserve test of windfarms. The test report follows the same template that is used when determining the contract volumes of windfarms following an operating reserve test.

Figure 3. below shows a graph of the FFR portion of the test. FFR is defined as the response to a frequency event/ injection 2 to 10 seconds after the event/ injection occurs. For existing Power Park Modules (PPM)s to qualify to provide system services they must provide greater than 1 MW of response within 2 seconds. The graph below shows Bann Road providing 2.94 MW of response within 2 seconds.

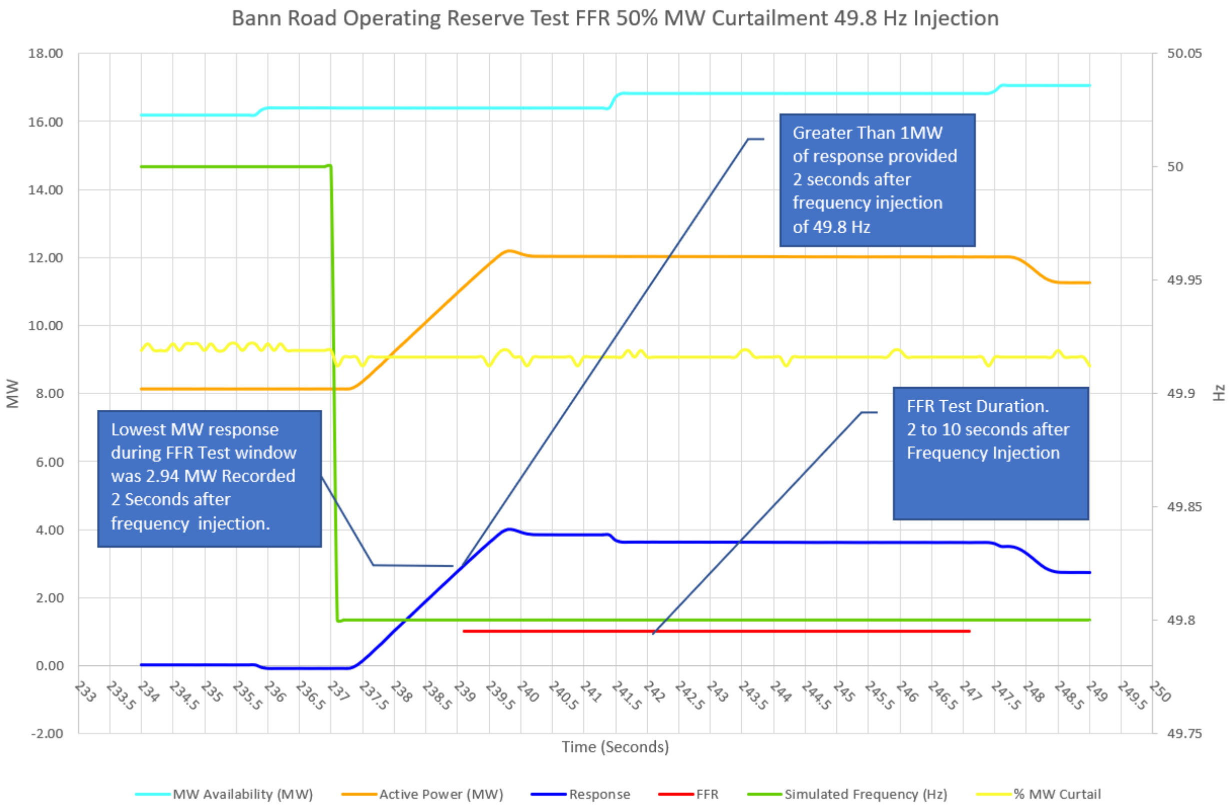


FIGURE 3. OPERATING RESERVE TEST % MW CURTAIMENT FFR

Table 1. Below indicates the volumes of each of the fast-acting services that Bann Road demonstrated successfully based on the operating reserve test report.

1	Proposed Maximum FFR Available Volume	**2.94 MW**
2	Proposed Maximum POR Available Volume	**2.72 MW**
3	Proposed Maximum SOR Available Volume	**2.54 MW**
4	Proposed Maximum TOR1 Available Volume	**1.97 MW**

TABLE 2. PROPOSED FAST ACTING SERVICES VOLUMES FROM % MW CURTAILMENT TEST.

5.1.5 OPERATING RESERVE TEST EMERGENCY ACTION ON

"Emergency Action On curtailment" as utilised by SONI in Northern Ireland is similar to the type of curtailment that is used by EirGrid in Ireland. As the SONI grid code does not require under frequency response to be provided when curtailed by "Emergency Action On" a temporary modification was made to Bann Road Solar's grid controller so that under frequency response when this type of curtailment is implemented could be demonstrated. Figure 4. below shows a graph of the FFR portion of the test. The graph below shows Bann Road providing 2.38 MW of response within 2 seconds.

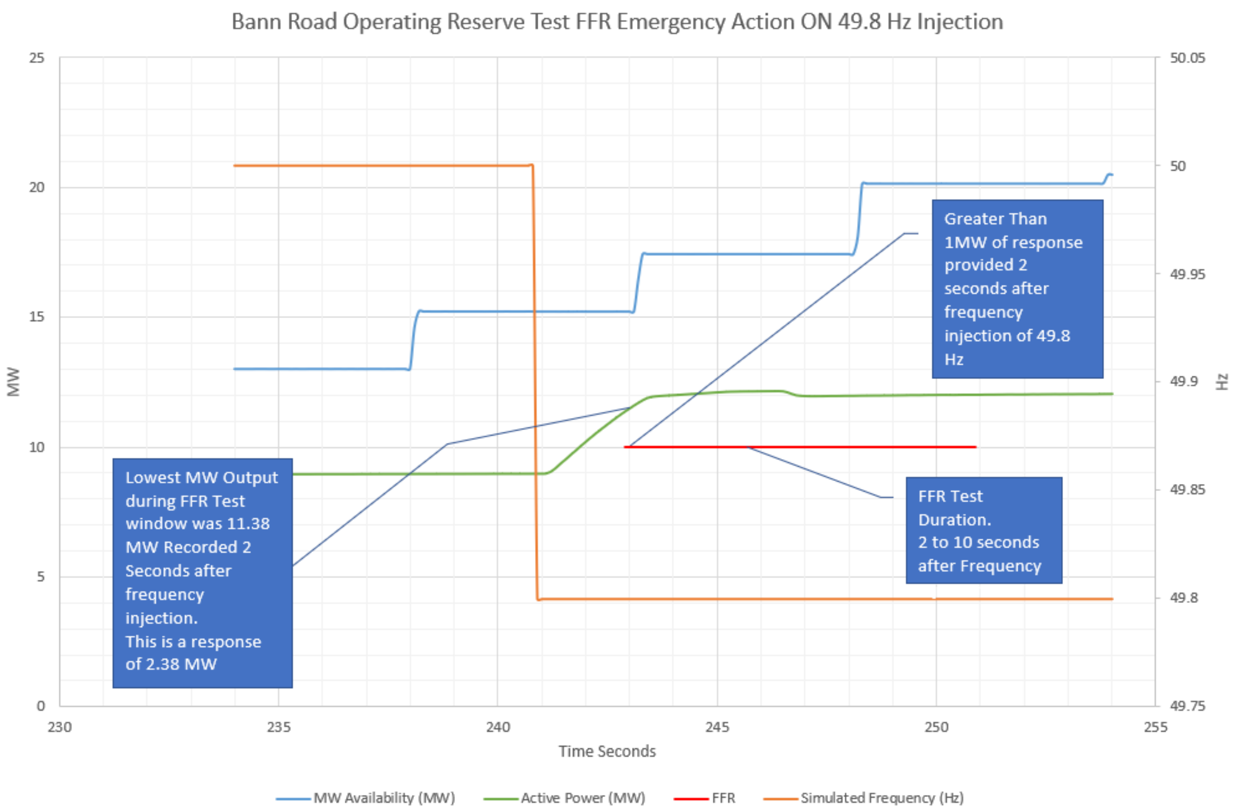


FIGURE 4. OPERATING RESERVE TEST EMERGENCY ACTION ON

Table 3. below presents the volumes of each of the fast-acting services that Bann Road would be eligible to contract for based on the operating reserve test report.

1	Proposed Maximum FFR Available Volume	**2.38 MW**
2	Proposed Maximum POR Available Volume	**2.97 MW**
3	Proposed Maximum SOR Available Volume	**2.86 MW**
4	Proposed Maximum TOR1 Available Volume	**2.62 MW**

TABLE 3. PROPOSED FAST ACTING SERVICES VOLUMES FROM EMERGENCY ACTION ON TEST.

PROVISION OF STEADY STATE REACTIVE POWER.

Bann Road is currently set up to import and export VARs in Voltage Control, MVAR control and Power Factor Control modes. The system will only import or export VARs while the site is exporting Active Power. The performance of the Solar Farm in exporting and importing VARs was assessed throughout the duration of the project.

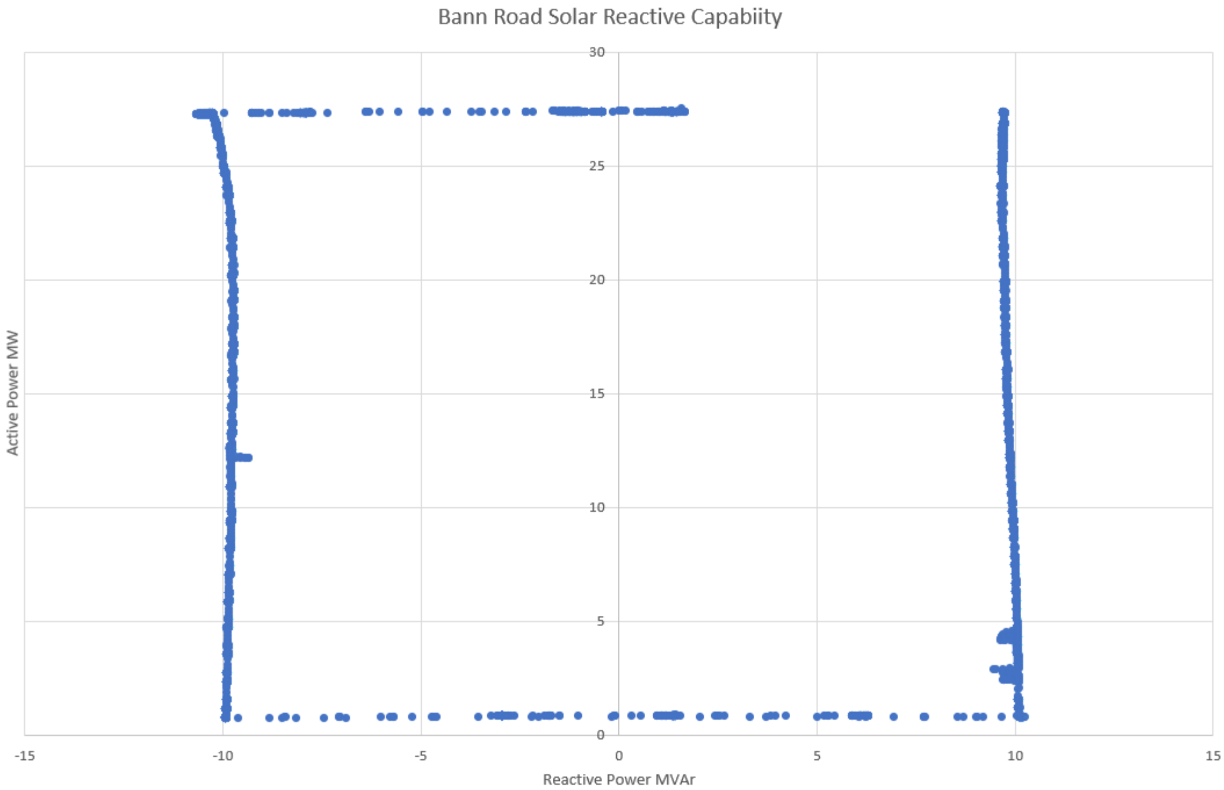
Data collected during the reactive power capability test performed during grid code compliance testing was used to complete the "DS3 SSRP test report". This report is the standard report that is used when determining contracted volumes for SSRP for Transmission connected PPM's. While Bann Road Solar is not transmission connected the fact that the report can be completed using the data from the same test that is performed when assessing SSRP volumes on transmission connected sites indicates Solar Plants may be capable in providing SSRP.

VARS AT NIGHT

The inverters on Bann Road Solar farm have the ability to provide VARs at night. During the application phase of the trial the possibility of testing the supply of VARs at night was investigated. However, the provision of Reactive Power at night (also known as "Q at night" or "VARS at night") could not be implemented because Bann Road was not originally designed for it. To provide reactive power at night DC the inverters will switch a DC voltage onto the DC side of the inverter. The Q at Night exposes the PV modules to Voltage potential at the worst possible time (cold and damp) and therefore increases the Potential Induced Degradation (PID) risk. PID is a phenomenon that causes significant damage to the PV modules so the installation of an "anti-PID kit" is required. The installation of an "anti-PID kit" requires switching to an IT earthing arrangement. Moreover, the installation of Insulation Monitoring Devices (IMD) is needed to safely operate the IT earthing. Changing to an IT earthing system would have required construction works, a new earthing study to be carried out and changes on the way the solar farm must be operated. Therefore, it was decided not to demonstrate reactive power at night as part of the project.

SSRP TEST REPORT

Data collected from the grid code compliance testing that was performed prior to the commencement of the trial was used to compile an SSRP test report for the site. Graph shows the reactive power capability of the site. Table 4 presents the SSRP volumes that the site would be eligible to contract.



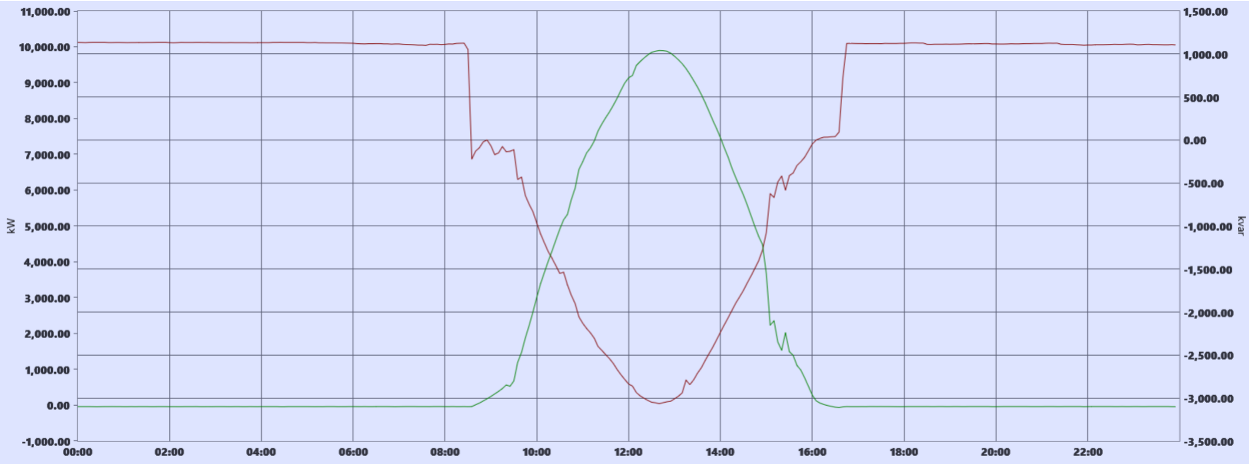
GRAPH 5. REACTIVE POWER CAPABILITY FROM MEASURED DATA

Reading	Value	Comment
Registered Capacity	29.81MW	
P range	1MW to 29.81MW	
Q range	-9.71 MVAr to +9.69 MVAr = 19.4 MVAr	(Qmin to Qmax as identified above in Section 7.3)
RP factor	(29.81MW – 1MW)/29.81MW = 0.966MW	Insert Calculation and value per Section 5.2
SSRP volume	(9.71 + 9.69)*.966=18.74	Insert Calculation and value as per Section 5.2
Q range at 0 MW	0MVAr to 0MVAr	
Cable Network Charging Capacitance including filters, *etc.*	0 MW, __+1.12_MVAr	Solar Inverters Not generating due to lack of Sunlight i.e. at night

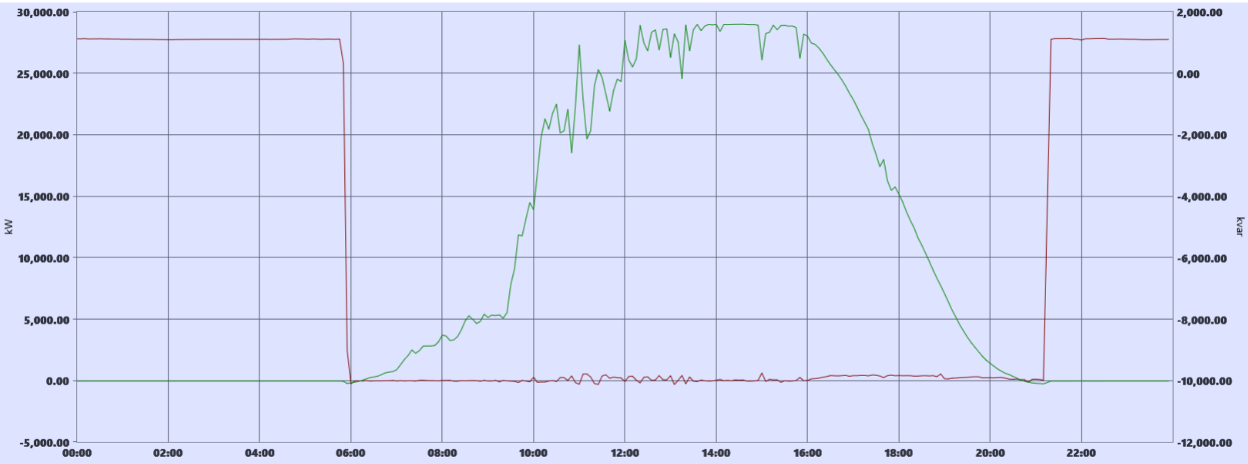
TABLE 4. SSRP CONTRACT VOLUMES

REACTIVE POWER USAGE

Below are sample graphs showing typical reactive power import while the site was producing active power. The graphs show active power export in green and reactive power import in red. From analysis of graph 2, which was recorded in January of 2021, the site was set by SONI/ NIE to control the import of reactive power in power factor control mode (Reactive power import in proportion to active power output). In comparison, Graph 3 shows the site operating in MVAr control mode importing a constant 10MVArs for the entire time that the site was exporting active power in August of 2021.



GRAPH 6. ACTIVE POWER EXPORT REACTIVE IMPORT 06_01_21



GRAPH 7. ACTIVE POWER EXPORT REACTIVE IMPORT 14_08_21

OPERATIONAL COMPLEXITIES

Frequency response services being provided from Solar Farms introduces two main operational complexities. These complexities are similar to operational complexities experienced by Wind Farms. Both are discussed below.

AVAILABLE ACTIVE POWER SIGNAL ERROR

A calculation of Available Active Power (AAP) is provided by all Solar Farms to the TSOs as a real-time signal. This signal is calculated based on Pyranometers and Reference cells located throughout the site which measure the solar irradiance. An analysis of the AAP signals was carried out to determine the accuracy of the available active power calculation. Three days where there was significant fluctuation in active power output throughout the course of the day were chosen. Graphs of the days that were analysed are shown in Graphs 8, 9 and 10. Windfarms are required to provide an Available Active Power (AAP) signal to EirGrid. The accuracy of this signal is monitored by comparing the calculated AAP signal to the actual output of the windfarm when the wind farm is not curtailed. The actual v predicted output is compared using a Normalised Root Mean Square Error calculation. The formula used in this calculation is given below.

The daily Root Mean Square Error (RMS_{Ud}) is calculated for Unit U on day d as:

$$RMS_{Ud} = \sqrt{\frac{\sum_{h=1}^{h=p}(AP_{Uh} - MG_{Uh})^2}{p}}$$

The Normalised Root Mean Square Error (NRMSUp) for a unit U over a period p is:

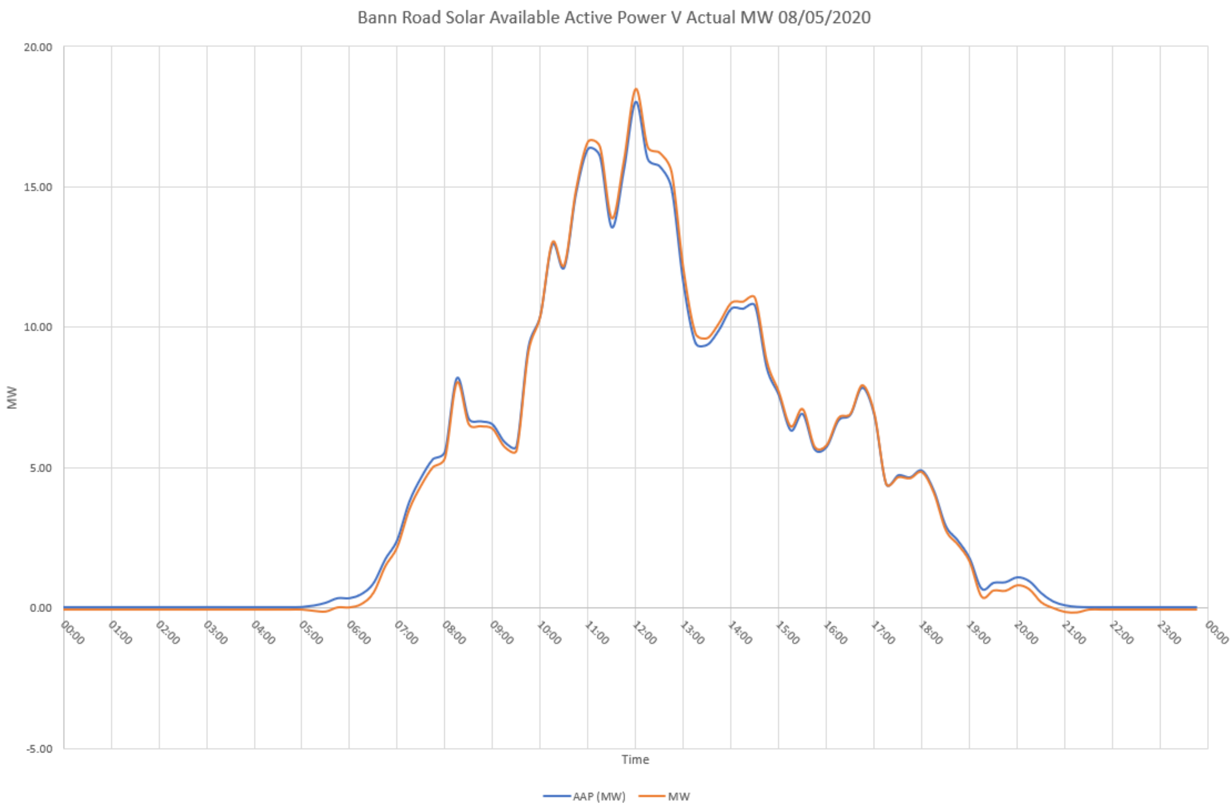
$$NRMS_{Up} = \frac{RMS_{Up}}{\max(\text{InstalledCapacity}, \text{MEC})}$$

Where installed capacity is the MW capability of the installed turbines on the side and MEC is the maximum export capacity as defined in the connection agreement. The Normalised root mean square formula was applied to the data for the three selected days on Bann Road. The results are contained in Table 5.

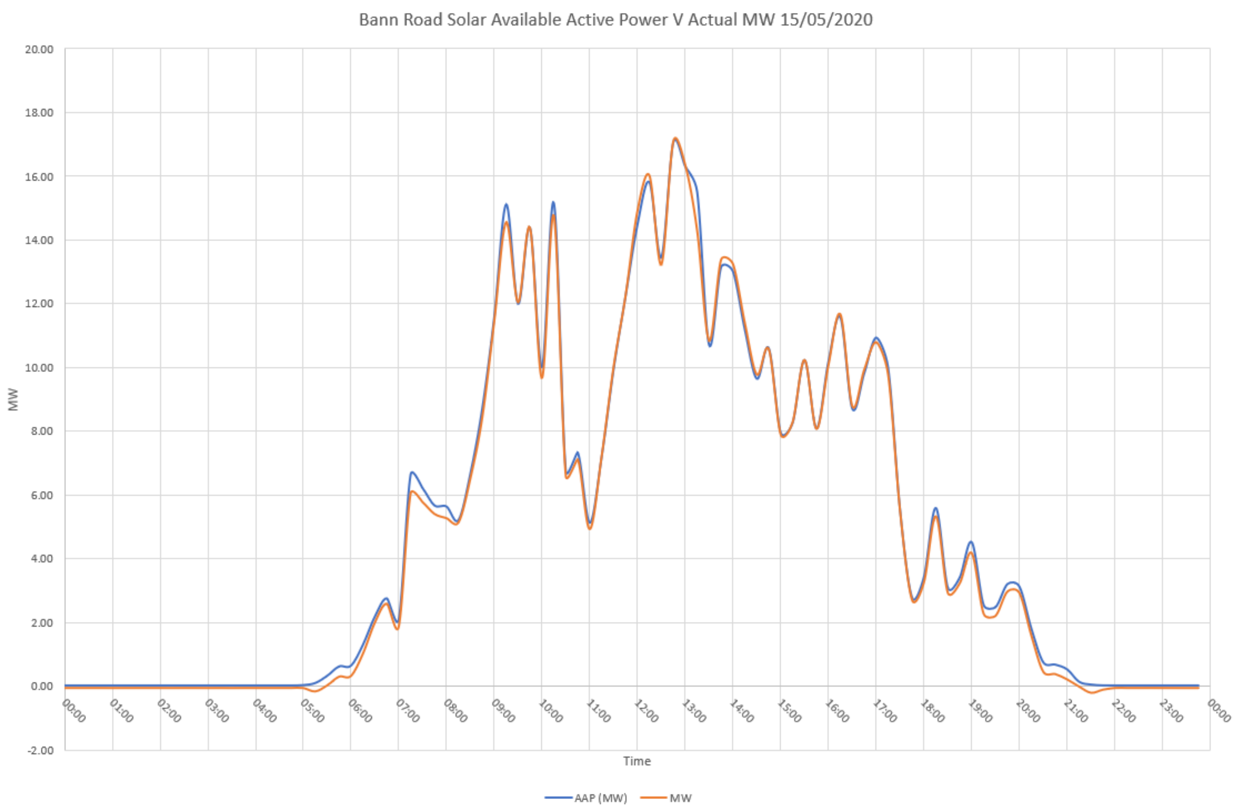
Day	NRMS Error
08/05/2021	0.69 %
15/05/2021	0.77 %
17/06/2021	1.06 %

TABLE 2

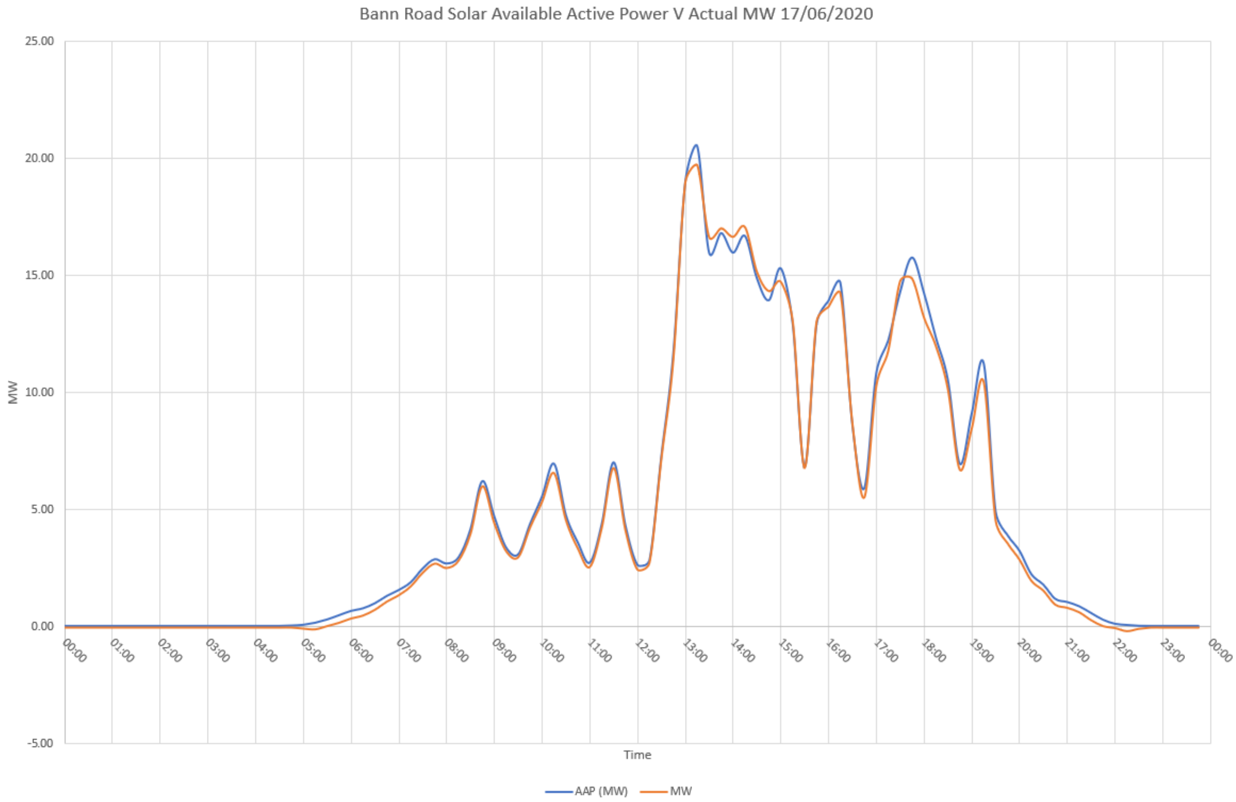
The current requirement on windfarms is that the NRMS error shall be less than 6%. The results from the analysis show that an accurate available active power signal can be provided by Solar Farms. When curtailed the amount of FFR and POR that is available can be determined by the difference between AAP and Actual output.



GRAPH 8. AAP ANALYSIS 08/05/2020



GRAPH 9. AAP ANALYSIS 15/05/2020



GRAPH 10. AAP ANALYSIS 17/06/2020

FORECASTING OF AVAILABILITY

For Solar farms the certainty of availability is not there given the variability of the resource providing it. Graphs 8 to 10 show how the output of a solar farm can vary significantly over the course of a day. Forecasting of reserve services from a solar farm requires the following to be predicted.

1. Available Active Power of the Solar Farm
2. Whether the Solar Farm will be dispatched down.

Whether a solar farm is dispatched down is at the discretion of the TSOs and is not possible for the operators of solar farms to predict. It is possible to provide a forecast of Available Active Power. In order to provide a forecast of solar farm output for a timeframe of within an hour ground-based sky imagery in conjunction with complex time series and machine learning algorithms are required. The accuracy of a forecasting system for solar was not part of the scope of this trial.

TRIAL OUTCOMES AND LEARNINGS

It is a finding of the trial that solar photovoltaic technology should be considered as proven technology for the fast-acting services of FFR, POR, SOR and TOR1, following a review by the Transmission System Operator. This ability of solar photovoltaic to provide these services was demonstrated by conducting an operating reserve test while the site was curtailed.

It is a finding of the trial that solar photovoltaic technology should be considered as proven technology for the provision of the DS3 service of "Steady State Reactive Power". This was demonstrated by the fact that SONI/ NIE were utilising the reactive power capability of Bann Road to support voltage on the grid throughout the duration of the trial.

Testing of solar technology during winter months is extremely difficult to complete due to the prevalence of frequent sudden dips in power output when clouds are passing over the site. On several occasions tests had to be restarted/ abandoned due to reduction in power output. To mitigate against this the following is recommended for consideration by the TSO:

a. Current operating reserve test templates for wind recommend curtailment to 40% MEC. For solar a curtailment to 20% MEC is recommended for the TSO to consider.

b. Perform testing during the summer months is the most suitable approach, however, it is recognised this is not always possible due to various factors.

c. It is a recommendation of Bann Road for the TSO to investigate the possibility of service providers being able to carry out unwitnessed operating reserve tests at short notice (i.e. less than 2 hours), given the variable nature of solar technology.

There is potential that Solar farms could provide "VARs at night". However, the initial electrical design of the site would have to have "VARs at night" capability incorporated into the design. The addition of VARS at night capability in certain circumstances after a site has been constructed could potentially incur a large amount of cost.

Forecasting of output from Solar Farms within an hour horizon requires the implementation of ground-based sky imagery technology. It is recommended that consultation with industry on the exact implementation of potential forecasting solutions is carried out.

6. RESIDENTIAL TRIALS

Following on from the success of the EirGrid Power Off and Save project, operational complexities associated with automated response from in-home technology is now being investigated. The objective is to explore the potential challenges involved in leveraging the flexible capability of the residential sector to provide System Services in the future. EirGrid and SONI envisage real benefits from DSM in reducing peak demands to the power system and the provision of essential System Services and recognise the importance of Demand Side Management to the delivery of energy efficiency targets. The system operator will use the project to investigate the potential delivery of residential grid services at scale, which has benefits in assisting Ireland to reach its renewable energy targets by providing greater flexibility in operating the power system with up to 70% renewable generation, which will require the ability to operate the power system with as much as 95% of generation from renewables at times.

In the 2019 QTP, two participants were successful; Energia and SMS (previously Solo Energy). Both participants implemented a different methodology and range of technologies as part of the trial demonstration of System Services capability.

7. ENERGIA RESIDENTIAL TRIAL

INTRODUCTION

To reduce the impacts of climate change energy systems are changing dramatically as electricity generation is becoming increasingly decarbonised and decentralised and electricity supply moves towards a digital customer centric model. Traditionally electricity is generated at large centralised fossil fuel power plants and passed to customers via transmission and distribution lines. In the early 2000’s this changed with the proliferation of distributed wind farms which supply the grid with renewable electricity. Today with the reduction in solar PV and battery costs and Government incentives individual consumers are starting to install their own Solar PV and battery systems to reduce their carbon footprint and save money on electricity, giving rise to the “prosumer”.

Consumers are installing batteries alongside their solar systems to store surplus electricity generated during the day which can then be used using renewable electricity generated from sunlight when required. Coupled with this SO’s must manage power with decreasing conventional fossil fuel generation and with an increase in intermittent non-synchronous renewable generation on the system. One solution to this is to supply system services using battery storage. Already large batteries are providing these services and in some markets such as Germany, Japan and the UK residential solar and battery systems are being investigated to manage frequency, voltage, and constraints on the grid. Through this Qualification trial Process (QTP) we will be joining these countries by investigating the viability of residential solar and battery systems to deliver flexible generation for the delivery of system services and explore the value to the end consumer and grid operators.

OBJECTIVES OF THE PROJECT

This project involves the distribution of solar PV systems with smart battery storage solutions. This will include 20 Residential installations on the island of Ireland. The objectives for this project are as follows;

- To prove aggregated residential electrical appliances as a technology class for the delivery of DS3 system services.
- To assess the operational complexities of the technology and the impacts this has on current TSO processes and systems.
- Investigate the barriers to System Services market entry for residential demand sites and investigate possible solutions.
- Operate the scheme with no adverse effects on the comfort of the consumer due to their involvement in the scheme.
- To maximise the value of smart products and develop a platform that facilitates individual residential customers to participate in demand side response and deliver DS3 system services.
- The knowledge captured from the QTP will help shape service development in the future and enable EirGrid to adapt quickly to emerging digital trends in the residential energy market.

SCOPE OF THE TRIAL

TABLE 1. SCOPE FOR THIS TRIAL PROJECT

Technical overview of the trial	**The trial will test whether the delivery of DS3 system services is possible using domestic batteries. EirGrid and Energia will co-operate throughout the trial to fully understand the capabilities of DS3 system services and Demand Side Management (DSM) in Ireland and the challenges it faces.**
What technology is installed	Each home will be equipped with at least 2 kW of Tier 1 Solar PV panels connected to the grid with an DC to AC solar inverter and a separately AC coupled Moixa Smart Battery fitted with a 2.4 kW inverter and 2 x 2.4kWh (Max 4.8kWh) LiFePO4 battery cells. The battery is fitted with Ethernet, Wi-Fi and GSM communications for remote monitoring and control. The battery is also equipped with meters to measure the output from the solar panels and battery and monitor in-home demand. The meters provided by Moixa comply where possible with the DS3 Performance Measurement Device Standards[1].
Services provided	The service provider will attempt to provide Secondary Operating Reserve (SOR), Tertiary Operating Reserve1 (TOR1) & Tertiary Operating Reserve2 (TOR2)[2]. In a frequency event the batteries are expected to respond as an aggregated unit within 15 seconds.
How the services are provided	A drop in frequency below 49.8Hz is measured using frequency meters. This results in a trigger to be sent to Moixa's Gridshare Platform. This in turn triggers the batteries to begin discharging to first the home and then the grid. The batteries can distribute charge for a maximum duration of 20 minutes.
Performance and data reporting and management	The GridShare platform will supply data for the project. The data from each event is stored on the GridShare Platform to carry out necessary performance assessments. For each event the expected response and achieved response will be measured. The extent of the difference between the expected response and the achieved response will determine how the Demand Side Unit (DSU) performed for each event. The performance of individual batteries will be reported at a sampling rate of 1 Hz (1 second granularity) in batches every 30 seconds.
What are the key results	To prove residential units can deliver DS3 product with no adverse effects to the end consumer.
Scope to trial Primary Operating Reserve (POR) and Fast frequency Response (FFR)	Potentially but issues with aggregating the responses and communications may create latency problems with delivery. To overcome these latency issues Hardware (H/W) and Software (S/W) upgrades may be required which may prove to be a significant cost barrier.

[1] As set out in the EirGrid Document 'DS3-Performance-Measurement-Device-Standards-for-Fast-Acting-Services' (http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-Performance-Measurement-Device-Standards-for-Fast-Acting-Services.pdf).
[2] As defined in the EirGrid Document 'DS3-System-Services-Protocol-Regulated-Arrangements_final' (http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-System-Services-Protocol-Regulated-Arrangements_final.pdf).

What other services can be provided	Potentially over frequency response.
Scope for ESB N and NIE involvement	Both DSO's can take learnings from grid connection processes specifically with Alternating Current (AC) coupled battery storage and solar systems where the battery and solar system are classed as 2 separate generators. Depending on interest in the project there may also be scope to install batteries in areas where the DNO are experiencing problems (due to constraint for example) and explore the use of residential DSR to potentially save cost through deferred grid upgrades.
Determine grid code, metering code, connection derogations requirements	We require a derogation from ESB for clause 4.7 as it is not applicable to domestic small-scale generation and energy storage. We also require derogation from ESB for the requirement to reduce generation at 2%/0.1Hz between the frequencies of 50.2Hz and 50.5Hz as it is not applicable to micro-generation at the domestic level. Both have been granted for the QTP by ESB.
Assess barrier to entry	High prices of systems. Not enough benefits to encourage battery uptake. Cost effectiveness.

PROJECT APPROACH

The project has run for 18 months with Energia taking full responsibility of the operations throughout. The trial project was distributed to 19 Energia Group customers. Industry and customer research were used to identify the consumer segments based on their experience and willingness to provide services. The sites chosen in the trial and the vendors responsible for the delivery of key services (Moixa & House2Home) were at the discretion of Energia.

PROJECT SCHEDULE AND PROGRESS AGAINST PLAN

This section outlines the progress against the project plan. The project was rolled out in a phased approach with each phase building on the next. This section summaries these sections and key deliverables to date. There were 5 main phases to delivering this project detailed with progress below;

Phase 1

- **Mobilise the project -** Relevant stakeholders agreed on the project scope and objectives and were successful in fulfilling the QTP requirements.

Phase 2

- **Testing the technology -** After installing the technology, the selected test participants went through the Moixa GridShare Flex integration and test phase to enable frequency response services.

Phase 3

- **Go Live -** Once all installations were satisfactory with the test participants, the remaining installations were carried out and QTP period officially started when they were all operational. Energia worked with EirGrid to ensure that the deliverables as outlined in Lot 2 of the QTP are delivered. This meant ensuring appropriate signal requirements and measurement devices are operating as per the DS3 System Services Regulated Arrangements where possible. The fleet of residential batteries successfully went live to the real-time grid frequency events on 30 March 2020.

Phase 4

- **Measurement and reporting of Data to EirGrid -** Energia was responsible for exporting data recordings in compatible Microsoft Office Application formats. Frequency trigger data was sent following events in electronic reports via a secured connection email to the TSO immediately following an event. Interpretation of this data and the learning's obtained from it led to a more in-depth understanding of the potential for the residential storage systems in Ireland to provide greater flexibility in operating the power system with higher levels of Non-Synchronous power generation. The battery fleet successfully responded to real-time frequency events, measurement throughout the event was successful and were successfully reported to EirGrid as expected. Analysis of data was carried out from both EirGrid and Energia with investigation around expected and achieved responses

Phase 5

- **Trial Publication and Conclusion –** The final report is delivered with the results and analysis of the trial. The solar PV and battery systems installed as part of the trial will continue in business in the usual manner (generating electricity sustainably during the day which can be stored by the battery for night-time use). If the value and/or revenue streams become available in the future the functionality for delivery of system services can be re-instated.

KEY DELIVERABLES AND MILESTONES FOR THE REPORTING PERIOD

This project aimed to deliver upon the requirements outlined in Lot 2 of the QTP namely;

- The provision of DS3 System Services from residential battery units.
- Investigate the barriers that exist in the current regulated arrangements to allow participation for residential Service Providers in the future.

The list of Key Deliverables for the QTP trial with work streams, description and status is listed in table 2 below:

TABLE 2. KEY DELIVERABLES AND MILESTONES FOR THE REPORTING PERIOD

Phase Type	Description	Status
Legal & Regulatory	On boarding – Privacy Policy, T&C's, Customer Contracts	Complete
Legal & Regulatory	Installation - Products and Installer Accreditation	Complete
People & Organisation	Recruitment & Onboarding - Marketing, Marketing Plan, Marketing Material	Complete
People & Organisation	Customer Communication Plan - Pre, During and Post Pilot Communication	Complete
Process & Fulfilment	Installer Readiness - Processes, Systems, Training	Complete
Process & Fulfilment	Installation - Supply chain, purchase and deliver stock	Complete
Process & Fulfilment	Installations – installations and Commissioning of Solar and Battery Systems	Complete (IE only)
Process & Fulfilment	Monitor & Reporting - Data capture, management, integration and analysis	Complete
Technology	Installation - Integration with Moixa GridShare	Complete

KEY ACTIVITIES AND ACHIEVEMENTS

7.1.1 PARTICIPANT RECRUITMENT

Energia recruited the participants using several marketing tools with industry and customer research to identify the consumer segments most likely to be interested and available to participate in the trial e.g. early adopters and consumers with a preference for Electric Vehicles and Solar PV. If a customer expressed interest an eligibly questionnaire was completed, if the customer was considered eligible a site survey of the home was completed to further determine eligibility and design a bespoke system for the customer. If the home was eligible and the customer was happy to proceed the installation took place shortly after the grid connection was granted. To encourage Energia customers to participate in the trial they were offered a discounted Solar and Battery system on the basis they were willing to provide data and feedback over the course of the trial. A communication strategy successfully recruited 19 interested and willing Energia customers in Ireland and one participant in Northern Ireland (NI) was also been recruited however a grid connection was not granted in the time frames of the QTP.

7.1.2 TECHNOLOGY DELIVERY

All participants received a Moixa Smart Battery and a Solar PV system (Figure 1). The Moixa Smart Battery features an integrated optimisation and control algorithm built on AI and machine learning called GridShare as well as a web dashboard and app which allows participants to see exactly how much electricity they are generating and consuming and how much solar energy is being used in the home (self-consumption), stored in the battery, or pushed to grid (exported).

All required training was carried out by product installers to ensure they were competent to carry out the installations. This included training to become Moixa Accredited Installers and completing all the required training to become part of the SEAI renewable installer register and be eligible to install systems for the SEAI domestic solar PV and battery grant scheme.

FIGURE 1. MOIXA SMART BATTERY AND SOLAR PANEL

Field management software was used to develop a seamless survey and installation process including quality assurance, customer communications around appointment setting and the delivery of relevant paperwork to the participant (e.g. SEAI grant application).

FIGURE 2 INSTALLED MOIXA BATTERY, SOLAR PV INVERTER AND OTHER ANCILLARY EQUIPMENT IN PARTICIPANT GARAGE

FIGURE 3. INSTALLED SOLAR PV

7.1.3 COMMUNICATION STRATEGY

The communications strategy developed for the project was executed successfully and has proven to be a useful framework to ensure effective communications between relevant stakeholders. Workshops were organised where appropriate and weekly and monthly meetings have taken place throughout the project.

7.1.4 CONSUMER ENGAGEMENT AND PARTICIPATION

A Consumer Engagement Plan was developed which includes a comprehensive customer support facility, which ensures any issues are addressed promptly for participants. Over the durations of the trial, customer engagement ran smoothly and there have been no significant negative issues from a communications perspective with no participant reporting negatively on their battery's responses. There have been some minor installation and hardware issues, the majority of these were detected remotely before a participant was aware, where possible issues were resolved remotely. If a remote resolution was not possible, it was escalated and was resolved promptly on site.

7.1.5 STAKEHOLDER ENGAGEMENT PLAN

A stakeholder management plan was developed to ensure all key internal and external stakeholders were identified and communicated with appropriately. Information on the project has been disseminated to the following external stakeholder groups:

General public - Social media coverage via Instagram, Twitter, LinkedIn and YouTube including a dedicated webpage on Energia's website. Energia also conducted presentations at a trade show. There was also some media coverage in a national newspaper and several online magazines ('e-zines').

Industry Stakeholders – Energia and EirGrid conducted several presentations to key industry stakeholders which included NIE, ESB and the CRU.

KEY ASSUMPTIONS & OUTCOMES

This section outlines initial assumptions made, assumptions made as the project progressed and the actual outcomes.

7.1.6 DSO GRID CONNECTION TIMELINE:

Assumption: The grid connection process will not adversely affect the installation timelines.

Outcome: ESBN derogations were requested and granted by ESBN, although the grid application process caused some minor delays it did not adversely affect the installation process. There was no issues or complications arising from the DSO connection process in IE.

Energia submitted a derogation request for a grid connection to NIEN, this was not successful. There is considerably more domestic rooftop solar in NI due to an incentive scheme that started in 2005 and ended in 2017. This has created a potential market for retrofitting batteries to existing solar PV in NI. As NIE has had derogation requests similar to the one Energia requested they were not in a position to grant it for the trial as it could be construed as undue favouritism in the market. Energia and Moixa have continued the dialogue with NIEN throughout the project and continue to investigate a cost-effective solution to manufacture a battery that meets the standard and regulation set out in the NI grid code with a goal to submit a successful grid connection application to install a battery in NI in the future.

7.1.7 BATTERY COMMUNICATION:

Assumption: Communications to the battery will not be interrupted for prolonged periods over the course of the trial. This assumes that the units will not be prevented from providing DS3 services for long periods of time therefore not impacting on the DSU ability to meet QTP requirements.

Outcome: There has been some short data gaps in data received from individual batteries to date, there have been no prolonged interruptions due to communications that were not resolved remotely or promptly by an installer call out.

7.1.8 LV NETWORK THAT WILL LIMIT DSR AVAILABILITY:

Assumption: Not being able to provide services due to a LV line being down. This assumes that the units would not be prevented from providing services for long periods of time causing minimal impact on the DSU's ability to meet QTP requirements.

Outcome: This has not been an issue for the project to date.

7.1.9 HUNTSTOWN FREQUENCY METERS OPERATED BY HUNTSTOWN POWER STATION BEING A VIABLE OPTION FOR FREQUENCY TRIGGERS FOR THE BATTERY FLEET.

Assumption: Energia frequency meters operated at Huntstown Power Plant will integrate Moixa GridShare. If the frequency falls below the reserve trigger (initially 49.8Hz and later reduced to 49.7Hz and then again to 49.6Hz) this will send a signal to GridShare which will in turn trigger each of the batteries to respond to the system event.

Outcome: Huntstown Power Station is a national piece of strategic infrastructure and has strict IT security, it was discovered sending signals in and out of its IT infrastructure was not possible in the time frames set out in the project plan. Energia contracted an external company with an existing frequency meter to deliver the API dispatch at the reserve trigger to GridShare which in turn triggered each of the batteries to respond to the system event. Automated emails were sent instantaneously with event details to Energia and EirGrid with further analysis of the event being delivered within 3-5 working days.

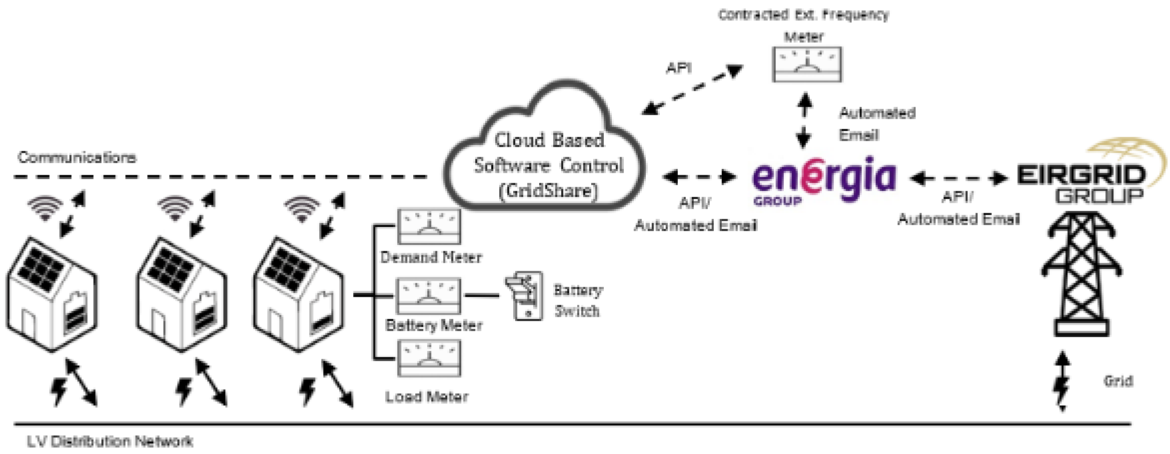


FIGURE4. REPORTING AND FREQUENCY TRIGGER SYSTEM CONFIGURATION

PROJECT RISKS, CONSTRAINTS AND OPERATIONAL COMPLEXITIES IDENTIFIED

The following items were identified as potential risks and constraints to the project that may affect the delivery of the project. As the project progressed some of these risks and constraints have affected the project and have resulted in some operational complexities, these were monitored and investigated as the project progressed. Overall given the risks and constraints below, the project still managed to respond real time frequency events on the grid and significant learnings were gained throughout the process.

7.1.10 METERING, MEASUREMENT AND VALIDATION

The batteries were fitted with Ethernet, Wi-Fi and GSM communications for remote monitoring and control. The battery is also equipped with meters to measure the output from the solar panels and battery and monitor in-home demand. The meters provided by Moixa comply with the DS3 Performance Measurement Device Standards where possible and deliver data at 1Hz. If Wi-Fi is lost in a home, this home will then be offline and not be available to respond to a frequency event reducing the impact of the fleet of batteries.

Operational Complexities Identified: There continued to be short intermittent data gaps from individual batteries, there may be various reasons for these which are discussed further in the report.

7.1.11 COMMUNICATIONS

Third-party providers communicated with the smart battery using the customer's broadband connection (Ethernet/GSM/Wi-Fi). In the event of performance issues with these communications between the Frequency Meter/GridShare and the Smart Battery Energia ensured that their third-party providers provided assistance and support in line with existing Service Level Agreements to facilitate communications breakdown and rectify any issues that may have arisen as soon as possible. This could have resulted in batteries being 'off-line' for short periods of time throughout the trial.

Operational Complexities Identified: Several communication issues were encountered throughout the trial due to a customer's broadband connection, the majority of these were detected remotely and resolved promptly.

Loss of unit on small trial has significant impact on service provision: With just 19 sites on the trial, if one site is to suddenly go offline this reduces the overall maximum response by 5%.

Operational Complexities Identified: This has happened several times, as the trial progressed they were resolved with no significant issues arising after the go live date (30/03/2020). Figure 5 illustrates the installed capacity against actual availability until the go-live date.

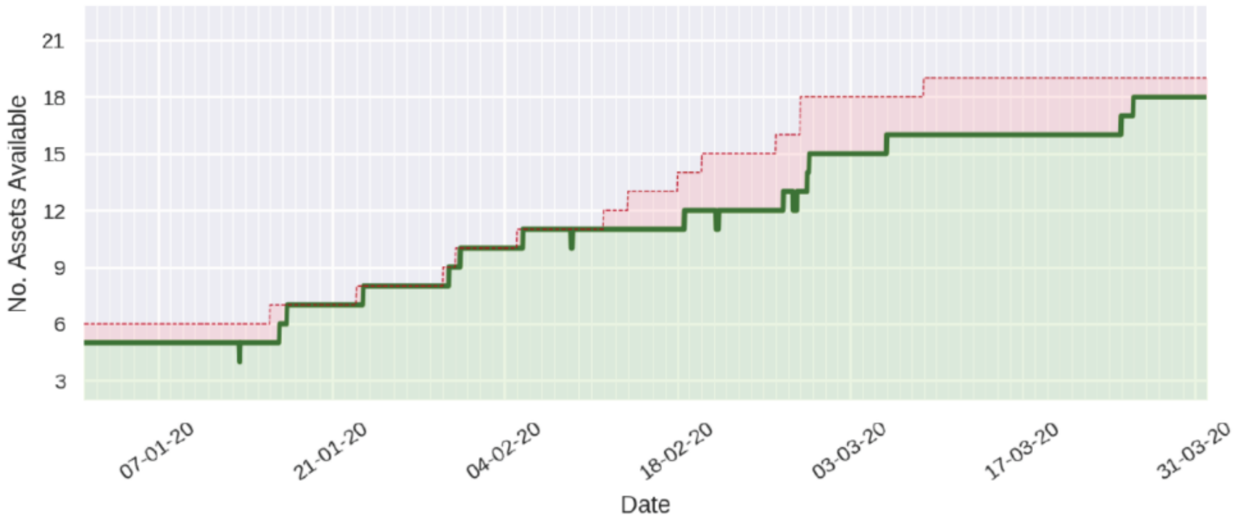


FIGURE 5. ASSETS INSTALLED VS ASSET AVAILABILITY (RED=INSTALLED, GREEN=AVAILABLE).

LEARNING OUTCOMES – RESULTS AND ANALYSIS

Since the fleet was launched for real time frequency events the frequency has dropped below 49.8Hz sixteen times. Initially a test batch of batteries (5 units) were made operational for live events, after the first event was successful the entire fleet was operational although some units were unavailable for various reasons. These were predominantly due to connectivity issues but also due to installation issues and hardware faults which were usually detected remotely and resolved quickly. The frequency threshold was lowered to 49.7 Hz due to the high frequency of events at 49.8Hz, after which seven frequency events were recorded. As the concept had been successfully proven, the frequency threshold was further reduced to 49.6 Hz. These reductions in the thresholds were implemented to reduce the regularity of the frequency events and to reduce the impact of the events on the end customer's battery performance and return on investment. However, some data for 2 events was not recorded due to an unforeseen database outage which involved a database reading/writing step resulting in failure of the fleet to respond. Redundancy measures were put in place to ensure similar outages did not occur for other events. The Moixa Dashboard relayed the details of each event to the participants. Energia sent three data sets to EirGrid for each event:

1. 30 seconds pre and 60 seconds post - event detailing grid frequency vs battery response.
2. The 20-minute response of the batteries (T-30secs to T+1260secs).
3. The State of Charge of the fleet of batteries throughout the events over a 3-hour period.

Table 3 gives a summary of all the events reported.

TABLE 3. OVERVIEW OF TRIAL GROUP EVENT DATA

Overview of Trial Group Event Data				
Event	**Date**	**Time**	**Frequency Trigger (Hz)**	**Number Batteries Participating in Response**
1 (Test Batch)	07/04/2020	21:04:02	49.79	5
2	11/04/2020	01:09:53	49.75	15
3	25/04/2020	22:53:12	49.79	17
4	01/05/2020	15:34:14	49.72	17
5	03/05/2020	21:44:14	49.79	17
6	06/05/2020	08:35:43	49.71	17
7	19/05/2020	10:28:47	49.67	17
8	18/06/2020	18:07:53	49.69	17
9	27/06/2020	15:23:26	49.61	17
10	07/07/2020	02:13:17	49.65	17
11	19/07/2020	05:26:29	49.7	17
12	25/07/2020	15:28:24	49.49	17
13	26/07/2020	00:22:01	49.68	17
14	23/09/2020	10:02:12	49.6	17
15	02/12/2020	08:18:55	49.6	17
16	14/02/2021	13:11:32	49.49	17

7.1.12 INDIVIDUAL BATTERY PERFORMANCES

An individual batteries utilisation is dependent on several factors, including but not limited to:

- Behaviour in the home which influences demand, for example, do the participants work 'regular' 09:00 – 17:00 hours, are they retired, or do they avail of variable tariffs which may influence when they use electricity.
- Number of electrical appliances in the home, how often they are used and their load profile. If a participant's home is not energy efficient, has number of large electrical appliances (e.g., washer, drier, electric shower, electric vehicle charge point, heat pump etc.) their electricity demand profile will be very high, when this is the case a batteries impact on overall electricity demand will be minimal when compared to a home that is energy efficient with no large electrical appliances and energy aware occupants.

To illustrate these variables, below are 3 examples of 3 different homes on the trial;

1. One with high demand and a variable electrical load each day.
2. One with low demand and a 'regular' 09:00 – 17:00 i.e., early morning and late afternoon/early evening spike in electricity demand.
3. One with a day/night tariff with early morning and afternoon spikes in electrical demand.

Each of these examples are based on the average daily profile for the length of the time the battery has been online. It is expected that these profiles will vary as the trial continues due to seasonality with potential energy insights offered through the GridShare platform also affecting participant behaviour. As the trial continues more accurate profiles will be developed as more data is gathered and analysed. The fleet includes many variations of the profiles demonstrated below (these represent actual profiles from trial participants) which affects the overall availability and spare capacity for the fleet to utilise when delivering a response for frequency events.

PROFILE OF HOME WITH HIGH ELECTRICAL LOAD PROFILE

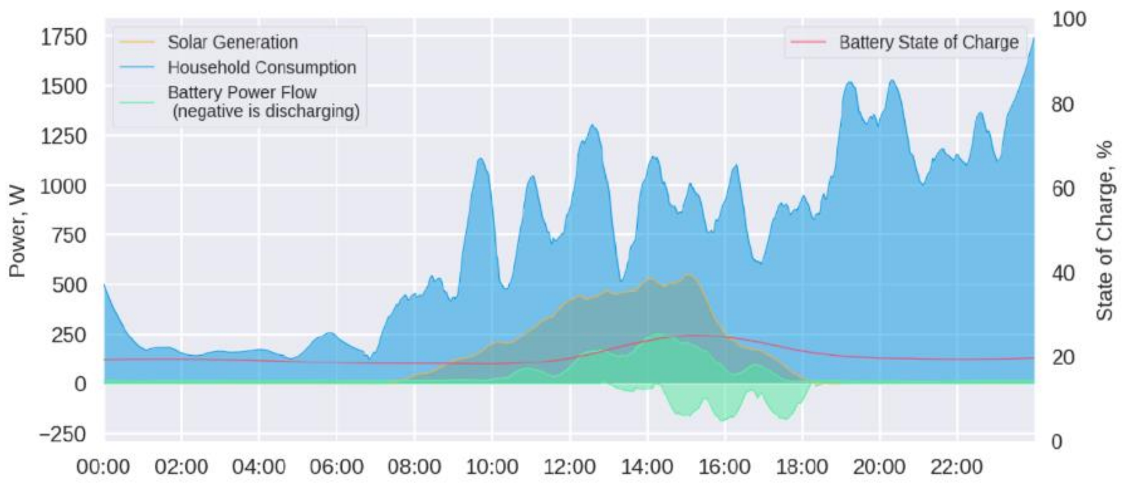


FIGURE 5. AVERAGE WEEKDAY ENERGY USAGE OVER THE REPORTED PERIOD – HIGH ELECTRICAL LOAD PROLIFE. SOURCE: MOIXA QUARTERLY REPORTS

The consumption of the house (Figure 5) was often too high to have any excess PV generation to charge the battery. When the Solar panels were generating electricity, most of it was consumed directly in the home. As solar generation increases and demand decreases coming into the summer months this will be expected to change with excess PV becoming available to charge the battery.

PROFILE OF HOME WITH REGULAR ELECTRICAL LOAD PROFILE

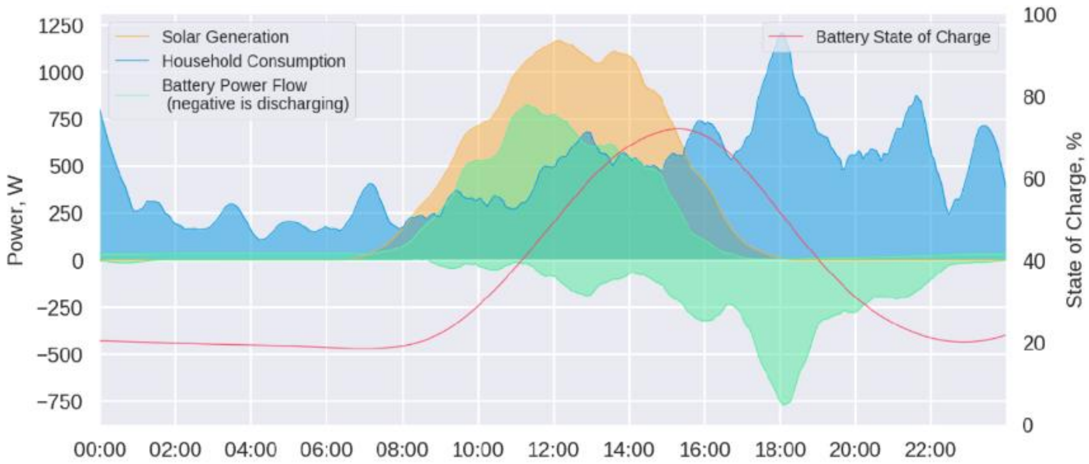


FIGURE 6 AVERAGE WEEKDAY ENERGY USAGE OVER THE REPORTED PERIOD – 'REGULAR' ELECTRICAL LOAD PROFILE. SOURCE: MOIXA QUARTERLY REPORTS

Figure 6 shows the average weekday energy profile where the consumption and generation profiles allow the battery to charge in the day and fully discharge in the late afternoon resulting in greater use of the battery and increased capacity and availability to take part in freq. response events.

PROFILE OF HOME ON AN ENERGIA VARIABLE DAY/NIGHT TARIFF

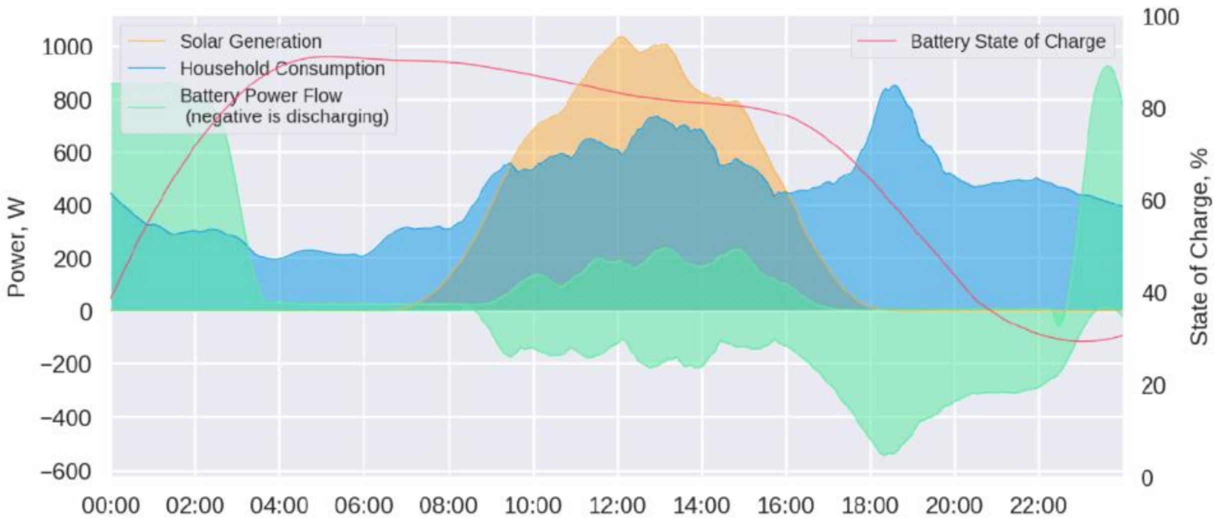


FIGURE 7 AVERAGE WEEKDAY ENERGY USAGE OVER THE REPORTED PERIOD –VARIABLE TARIFF PROFILE. SOURCE: MOIXA QUARTERLY REPORTS

Figure 7 illustrates a battery configuration that takes advantage of differences in tariff electricity prices. The battery fully charges between 11pm and 3am, discharges in the early morning, charges again with the PV excess and fully discharges when the consumption rises at 6pm. The average SOC difference is nearly 80% in this case with high availability and capacity for utilisation for a freq. event response.

7.1.13 FREQUENCY EVENTS RESULTS

There are several variables (behaviour, appliance usage, location, solar system size, and tariffs) that have an impact on the power available in the fleet. This section details the results of some early events. The events reported operate as a *Basic Static response.* This means that the Trigger Range is set to 0 Hz, so the unit provides its entire response when the frequency threshold is breached and continues even if the frequency recovers during the 20 min response which is often the case. Various data gaps were caused by individual batteries not reporting for short periods of time. Each battery is streaming data at 1Hz (every second) and each gap typically lasted no more than one second. The reason for these data gaps were investigated and it is suspected are attributable to intermittent home WIFI connections. After analysing the data post-event it was found that the fleet performed strongly delivering all the available power reported as available at the time of the frequency event. Forecasting fleet availability based on historic consumption patterns and the weather forecast is possible although due the variability of both the weather and participant behaviour accuracy diminishes with time. Table 4 gives the summary of observations from all sixteen events.

TABLE 4. SUMMARY OF TRIAL GROUP EVENT OUTCOMES

Event	Time of frequency event	Response Time (Seconds)	Aggregated Fleet Charge at T-0	Discharge	No. of batteries responding
1	09:04 PM	10	35%	5%	2
2	01:09 AM	8	41%	1%	5
3	10:53 PM	10	23%	2%	2
4	03:34 PM	9	75%	10%	15
5	09:44 PM	7	40%	6%	10
6	08:35 AM	13	53%	3%	10
7	10:28 AM	13	45%	10%	11
8	06:07 PM	10	27%	2%	2
9	03:23 PM	9	48%	12%	17
10	02:13 AM	9	34%	4%	5
11	05:26 AM	10	30%	2%	6
12	03:28 PM	10	43%	9%	12
13	12:22 AM	9	21%	2%	4
14	10:02 AM	10	25%	1%	3
15	08:18 AM	15	28%	4%	4
16	01:11 PM	30	21%	3%	3

The data collected in Table 4 corresponds to the following measurable outcomes.

1. **Response Time:** Is the time in seconds measured from T-0 for the aggregated fleet to deliver its full response in kilowatts.

   In the Figure 10 the response time recorded for event 4 is represented by the purple box and is 9 seconds in duration. The grey box shows the how the fleet sustains the full response with reduced performance attributable to data gaps.

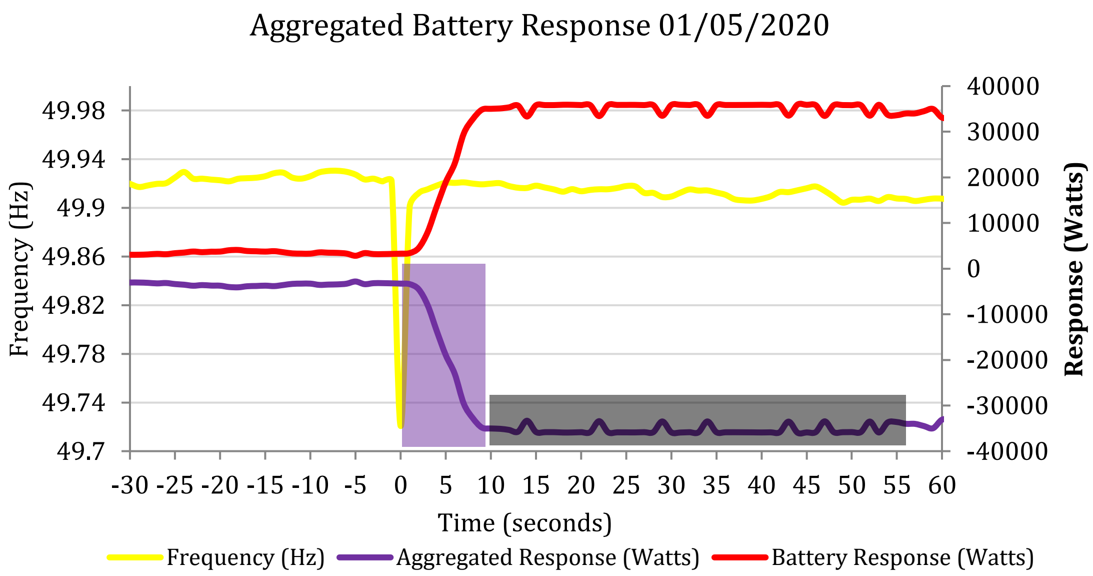


FIGURE 8 BATTERY RESPONSE TIME

2. **Aggregate charge at T-0:** This is the mean state of charge present in the entire battery fleet participating in the response recorded at T-0.

3. **Maximum Discharge in Response:** This is the change in the aggregate charge that takes place in the battery fleet from T-0 to T+120 Seconds in response to the frequency event.

   In the Figure 11 the maximum discharge in response is represented by a red circle, the fleet response resulted in an aggregated fleet discharge of 10%.

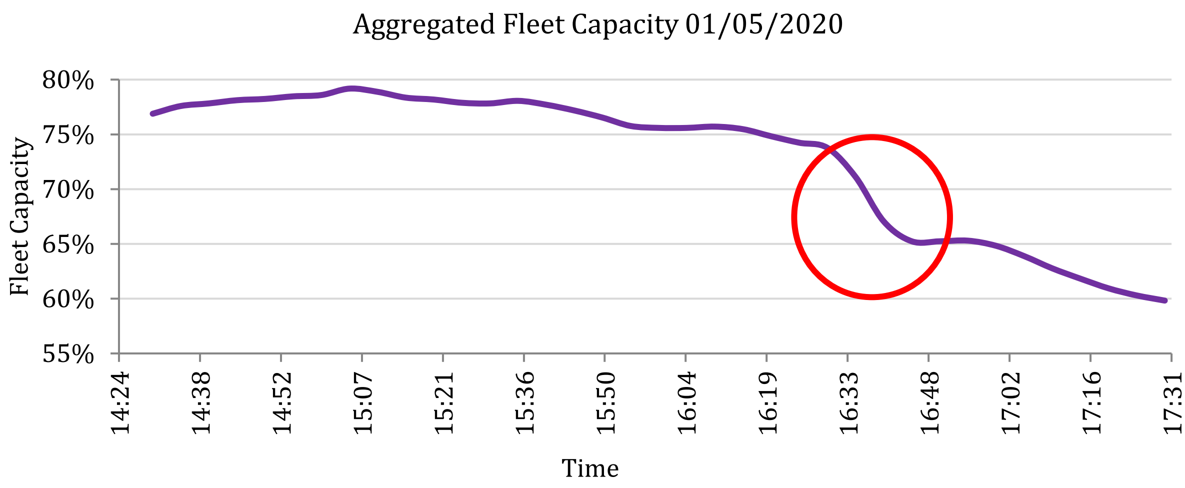


FIGURE 9 AGGREGATED FLEET DISCHARGE

4. **Number of Batteries Responding:** The individual batteries are configured such that they stop discharging after the state of charge has reached 20% in view of health and safety concerns of the batteries. Thus, the number of batteries contributing in real to the aggregated fleet discharge in response to a frequency event varies depending on the individual battery state of charge. Thus, the number of responding batteries is the count of batteries in the fleet whose state of charge is much above 20% and depreciate significantly after T-0 after the frequency has dropped.

RESULTS AND DETAILED ANALYSIS OF THREE EVENTS

In Tables 5 and 6 for event 6 and 7 below real-time reporting is shown in the 'T-0 columns' and shows the power reported as available at the time of event, the accuracy of real-time reporting is high with any small discrepancies accounted for by the impact of data gaps. The differences in real-time and actual performance are highlighted by the 'Δ%' columns. The difference in available power and delivered power by the fleet can once again be accounted for the data gaps, post event analysis has shown the fleet delivered the power reported as available at T-0.

The average power across the event accounts for all energy output by the units but does not provide information about the shape of the power output over time.

The minimum power across the event neglects the contribution from devices that run out of energy partway through the event but captures a pulse that is the true output over time.

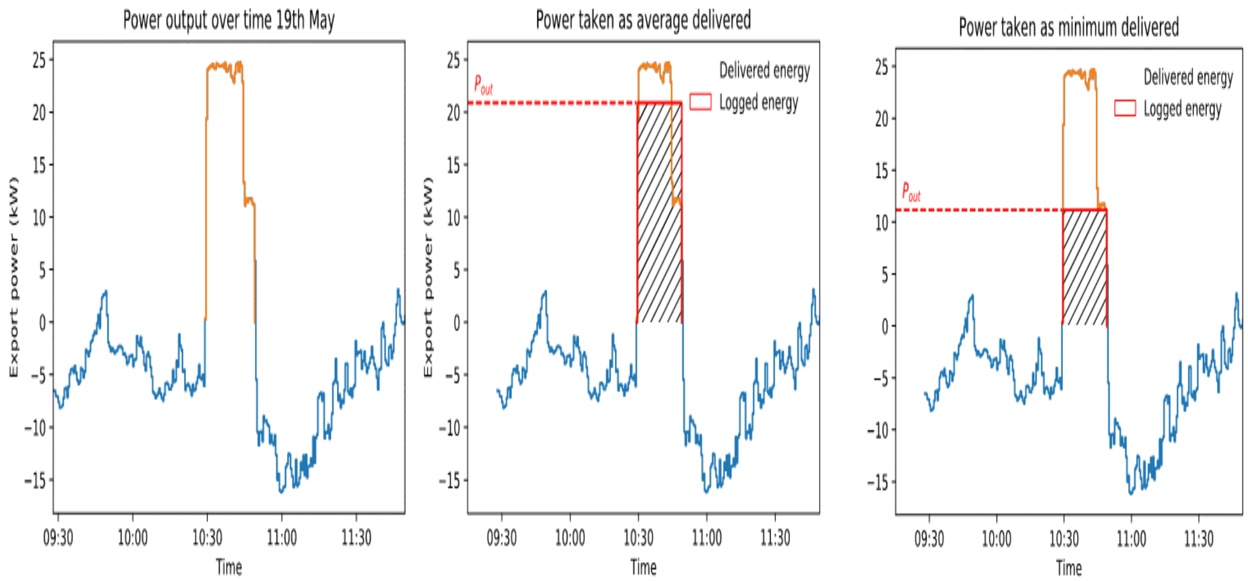


FIGURE 10. GRAPHS SHOWING POWER OUTPUT, AVERAGE POWER, AND MINIMUM POWER FOR EVENT ON 19.05/2020

Event 6 – (6/05/2020 – 08:35:43)

The three graphs below illustrate the details of the aggregated response of the battery fleet.

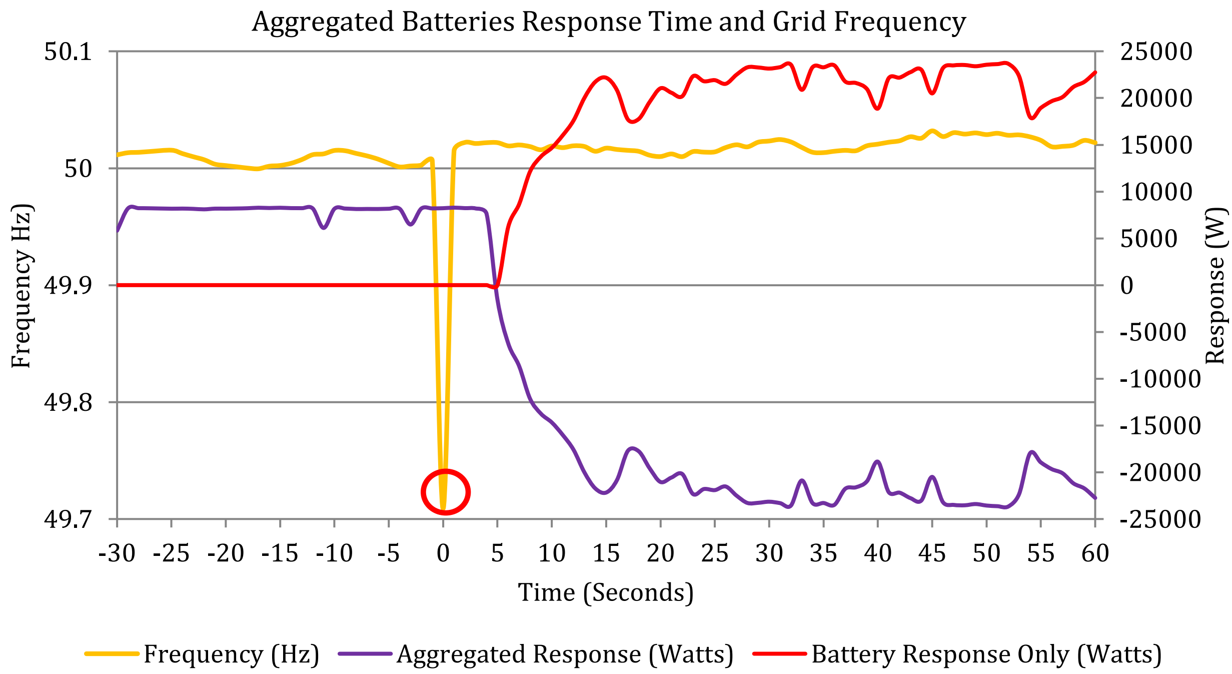


FIGURE 11. AGGREGATED BATTERY RESPONSE TIME AND GRID FREQUENCY (06/05/2020)

In the Figure 14 the frequency drop can be seen at time zero (circled in red). The batteries start responding almost instantaneously and are at full response within 10 seconds and would have successfully qualified for the full SOR service. They are still ramping up to full response at 5 seconds and therefore would not have been eligible for the full POR service.

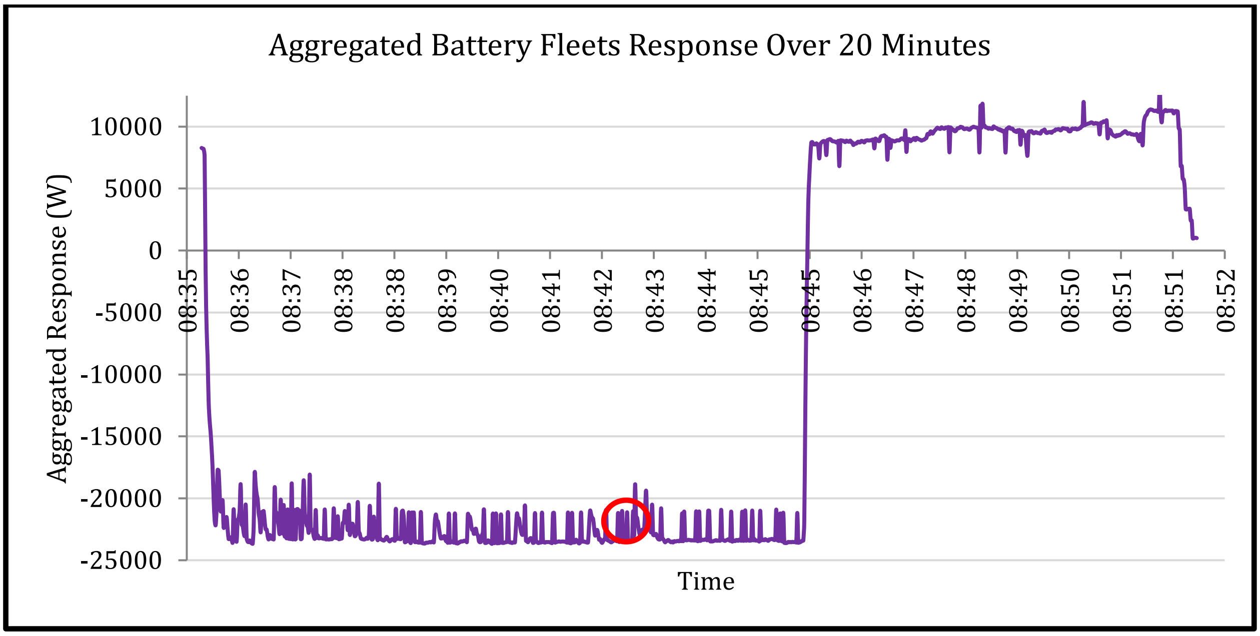


FIGURE 12. AGGREGATED BATTERIES 20 MINUTE RESPONSE (06/05/2020)

The fleets response lasted 10 minutes due to a configuration error which is clear in Figure 15. The sporadic data gaps are also clearly visible with one circled in red.

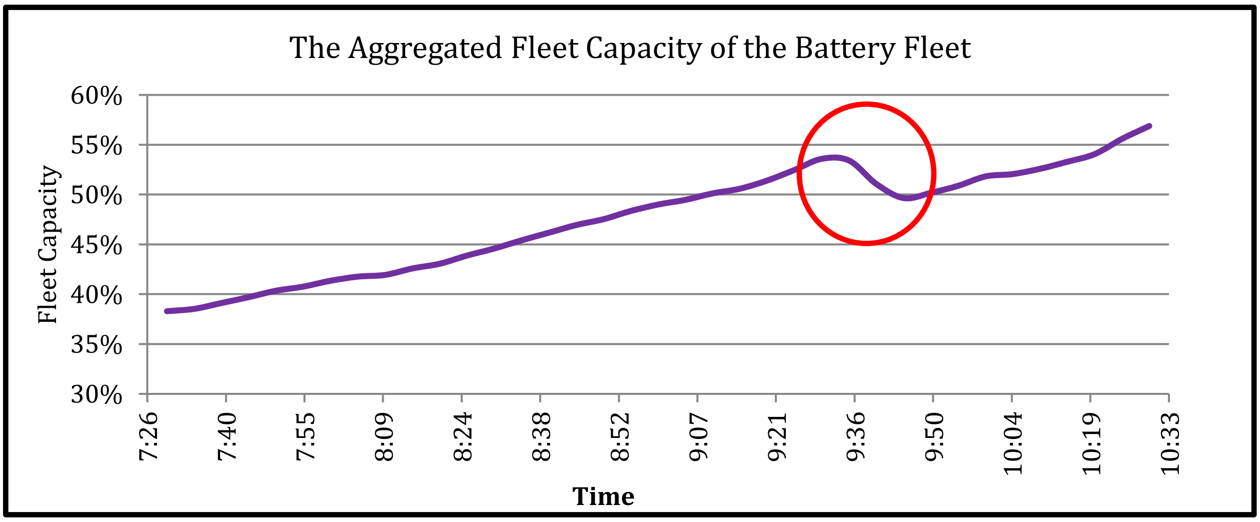


FIGURE 13. THE AGGREGATED CAPACITY OF THE BATTERY FLEET (06/05/2020)

Figure 16 shows the lack of spare capacity caused by the time of the event; it is clear there is not much spare capacity for the response. This coupled with the fact an individual battery is programmed to discharge at the maximum rate the battery inverter offers means the actual response as a percentage of the fleet in kWh is minimal (circled in red).

TABLE 5. THE AGGREGATED CAPACITY OF THE BATTERY FLEET (06/05/2020)

6th May	T-1h	T-1min	T-0	Delivered	Δ%	ΔkW
Average Power (kW)	28.13	28.42	28.42	22.37	79%	6.05
Minimum Power (kW)	26	26	26	22.26	86%	3.74

Table 5 shows the differences between available power and actual power delivered. The differences in these values can be accounted for by the data gaps displayed in Figure 13. After analysing the data post event the fleet delivered 100% of the power reported at T-0.

Event 7 – (19/05/2020 – 10:28:47)

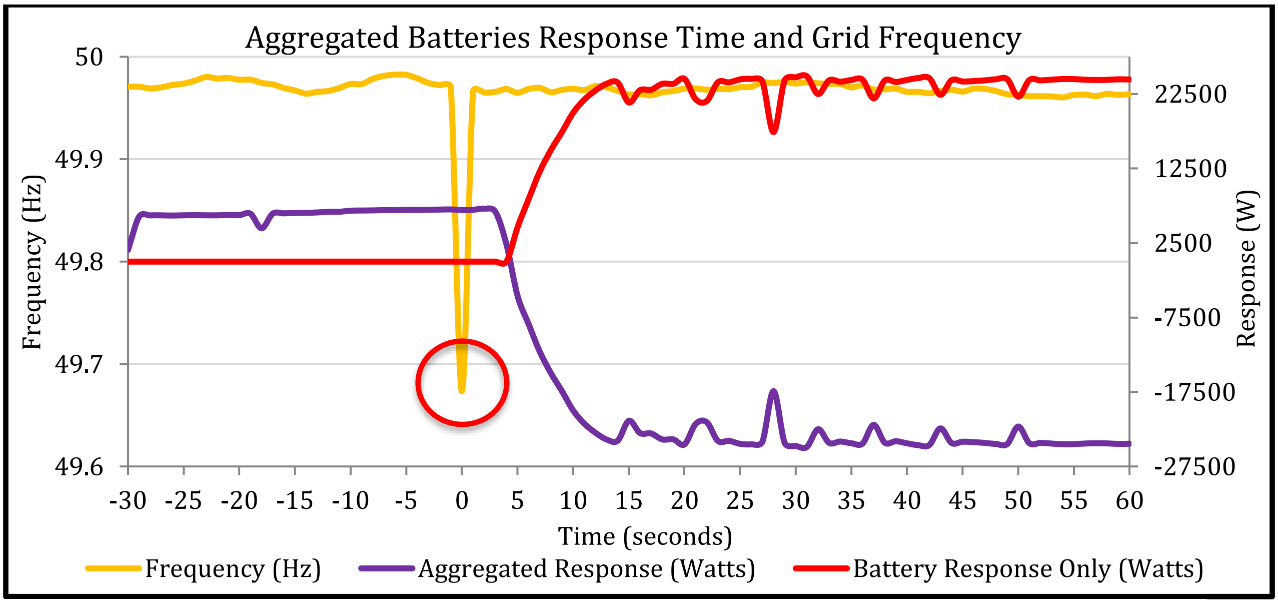


FIGURE 14. AGGREGATED BATTERY RESPONSE TIME AND GRID FREQUENCY (19/05/2020)

In the Figure 14 the frequency drop can again be seen at time zero (circled in red). The batteries start responding almost instantaneously and are at full response within 10 seconds and would have successfully qualified for the full SOR service. They are still ramping up to full response at 5 seconds and therefore would not have been eligible for the full POR service.

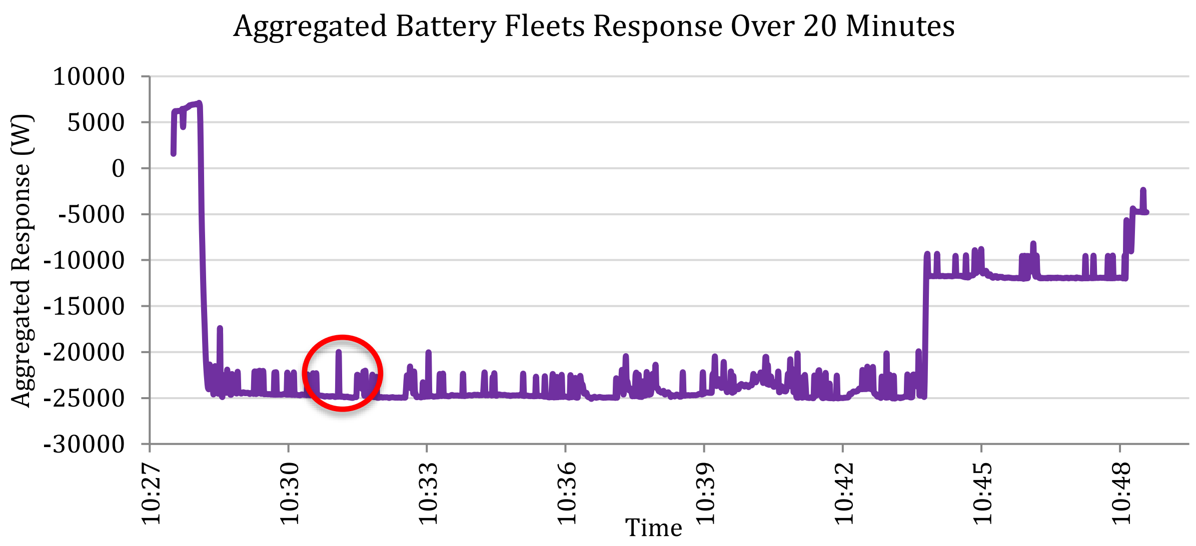


FIGURE 15. AGGREGATED BATTERIES RESPONSE OVER 20 MINUTES (19/05/2020)

In figure 15 the fleet had been successfully configured to respond for the full 20 mins proving the full SOR1, TOR1 and TOR2 services are achievable.

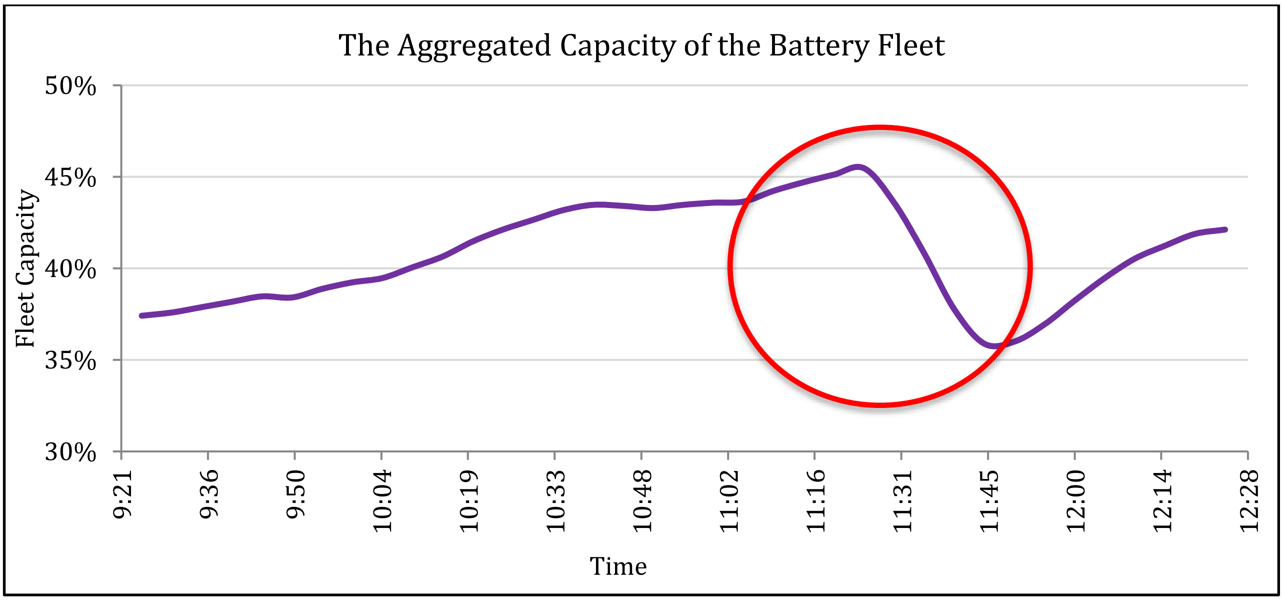


FIGURE 16. THE AGGREGATED CAPACITY OF THE BATTERY FLEET (19/05/2020)

At the time of the event the fleet is close to 46% capacity and discharges 10% of its capacity throughout the event (circled in red). Resulting in a far larger and more pronounced response than the early morning event and highlights the difference the time of a frequency event can have on the availability of fleet capacity to generate a response.

TABLE 6. THE AGGREGATED CAPACITY OF THE BATTERY FLEET (19/05/2020)

19th May	T-1h	T-1min	T-0	Delivered	Δ%	ΔkW
Average Power (kW)	27.02	28.46	28.32	21.14	75%	7.18
Minimum Power (kW)	16.8	24	24	11.16	47%	12.84

In table 6 there is a difference between reported availability and the actual response reported in the real-time due to data gaps, after analysing the data post event the fleet delivered 100% of the power reported at T-0.

Event 16 – (14/02/2021 – 13:11:32)

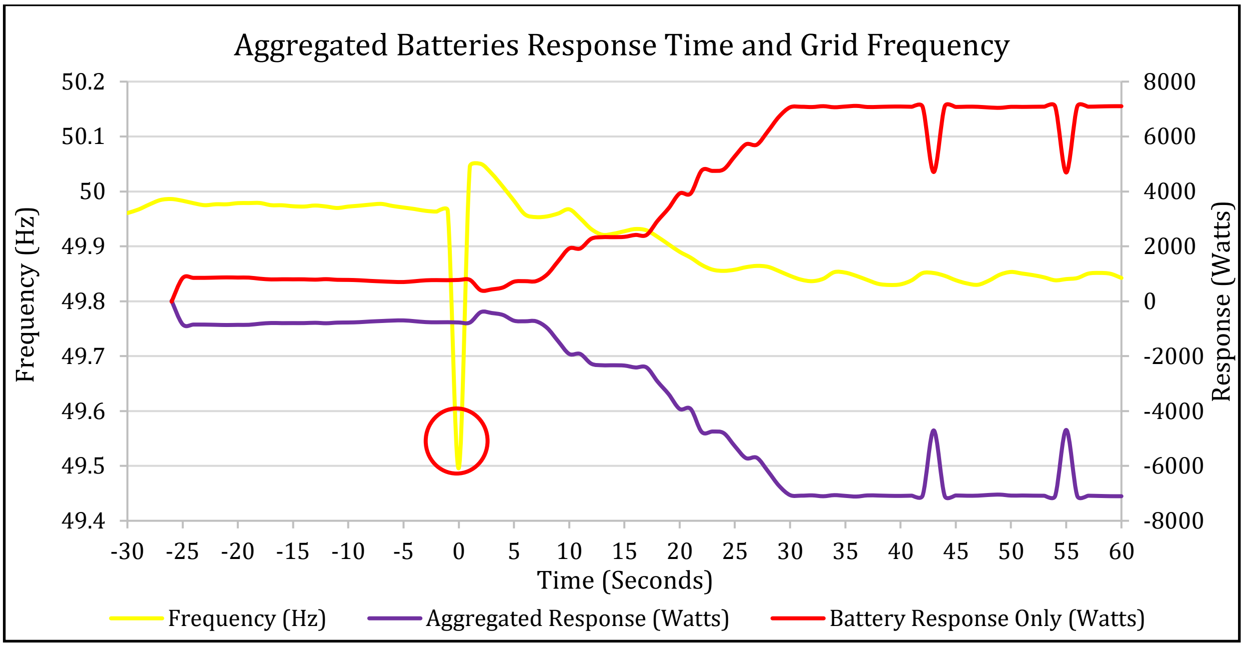


FIGURE 18. THE AGGREGATED CAPACITY OF THE BATTERY FLEET (14/02/2021)

In the Figure 18 the frequency drop can be seen at time zero (circled in red). The batteries start responding almost instantaneously and are at full response after 30 seconds which would have successfully qualified for a partial SOR service. They are still ramping up to full response at 5 seconds and therefore would not have been eligible for the full POR service.

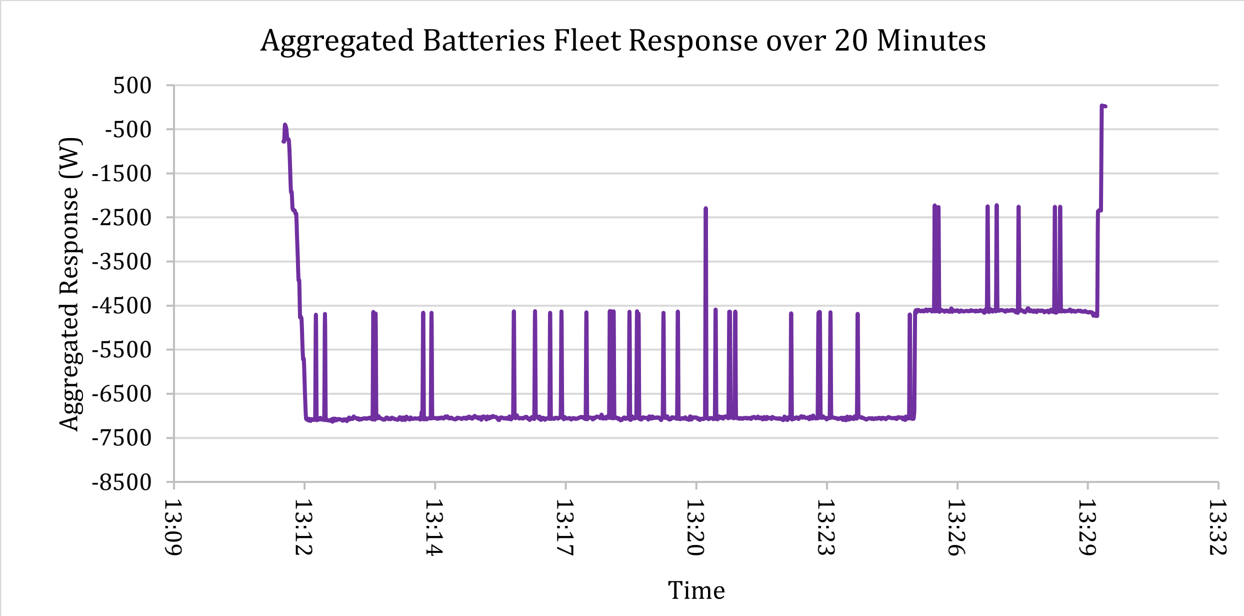


FIGURE 18. AGGREGATED BATTERIES RESPONSE OVER 20 MINUTES (14/02/2021)

The fleet was successfully configured to respond for the full 20 mins proving the TOR2 service is achievable with the fleet.

CONCLUSION

The events of this trial have successfully illustrated the operational capabilities of the fleet and proven the concept that a fleet of domestic batteries can respond to provide an aggregated response for SOR1, TOR1 and TOR2 and a partial response for POR1. It also highlights the operational complexities of delivering system services using domestic batteries. No adverse effects on the participants comfort in the home were reported by the battery's response during the trial.

RECOMMENDATIONS

Energia would recommend amending the current DS3 system services technical requirements to allow for more cost-effective metering and reporting that would be more applicable to a domestic setting.

PROVENABILTY OF SERVICE PROVISION

As a proof of concept, the fleet has delivered an aggregated response to for SOR, TOR1 and TOR2. Currently, FFR and a full POR response seem unlikely, unless frequency meters are located onsite with upgrades required in the metering hardware to allow for millisecond monitoring, measurement, and validation. These services could be achieved by allowing more suitable, cost effective frequency meters and metering requirements to be used to avoid a significant negative impact on the cost to manufacture and install the batteries.

8. SMS RESIDENTIAL TRIAL

EXECUTIVE SUMMARY

This report is being delivered as the final report of the eServe Project which is being conducted by SMS[3] as part of the D3S Qualification Trial Process (QTP) for EirGrid. The report sets out the main learning and outcomes of the project.

The eServe project established a trial group of 30 domestic properties which included the following technologies: 19 batteries, 10 smart EV chargers and 1 bi-directional EV charger (V2G). Recruitment of these participants came from the inclusion of properties from previous smart grid studies in which SMS was involved. SMS also teamed up with a large energy supplier to identify and recruit additional properties with EV's/EV chargers which could be integrated as part of this trial.

SMS entered the project with its Virtual Power Plant software, namely FlexiGrid, in existence. However, over the course of the project several limitations were identified with solutions / fixes delivered, resulting in improvements to the FlexiGrid platform and service delivery from the above-mentioned technologies. We also identified areas for improvement with the installed technologies and worked with the manufacturers to better enable their technologies to deliver grid services.

The project has been able to demonstrate that the delivery of a subset of DS3 system services is possible from the technologies in domestic properties. However, the project has also shown that because of practical and technology maturity reasons these technologies are not reliably able to deliver the full suite of DS3 system services. Since this project commenced, other battery technology manufactures have developed faster responding solutions, which could be used in future demonstrations to deliver the full suite of DS3 System Services.

Beyond technological constraints, the way in which value is apportioned amongst stakeholders (asset manufacturer, aggregator, energy supplier, system operator and end consumer) in a way which is equitable and attractive to all remains a critical barrier to further roll out. It was felt that that projects like EirGrid's QTP are important to steer the readiness of the individual technologies as well as the control platforms and business models required to deliver meaningful system services from domestic properties.

[3] The original contracting party, SMS Limited, is a wholly owned subsidiary of SMS plc and is referred to as 'SMS' throughout this report.

INTRODUCTION

The objectives of the eServe Project were to demonstrate the provision of DS3 system services from residential properties and investigate the barriers within regulated arrangements that inhibit the participation of residential service providers. The project was tasked with establishing a trial group of residential properties with a selection of technologies suitable for the provision of system services. The high-level tasks defined at the outset of the project included;

- Modify existing signalling to ensure compliance with DS3 regulated arrangements signal requirements
- Submit connection applications (NC6 microgeneration) and install related hardware at new customer sites
- Install appropriate metering solutions and/or consider alternative standards
- Establish and successfully test two-way communication with the NCC via the EDIL interface
- Customer engagement and management throughout the project including, management of installations, communications, query handling, event notification and all necessary GDPR related activities
- Secure DSO consent prior to commencement of trial
- Monitor the performance of the systems during system events/disturbances

APPROACH

Our examination of DS3 grid services focused on non-conventional domestic sources including Batteries and EV chargers. Our approach to the trial had to change due to the impacts of COVID-19 on how we could interact with properties to get assets connected. Firstly, we targeted existing assets and units which could have their software updated remotely, thus not requiring any site visit. COVID-19 also impacted the operation of the assets we were monitoring and controlling, for instance the requirement to work from home significantly reduced the number of miles the EV's were driving which, in turn, impacted how often they needed to charge.

The recruitment of participants for this trial focused on properties from previous trials in which SMS was involved. This had many advantages such as, the home occupants are already knowledgeable on the products and any installation issues had been previously resolved. Where new properties needed to be identified, we partnered with an energy supplier and reached out to their customer base and EV forums to identify interested parties. Many newly recruited participants were early technology adopters and interested in the potential additional features of their EV chargers. All participants benefitted financially in the form of credit applied to their electricity bills, for allowing their assets to be used to deliver grid services. The amounts paid were significantly above what would be commercially viable, but it ensured buy-in from the participants for the purpose of the trial. Some participants also benefited from a technology upgrade. For instance, many of the EV chargers where not ordinarily connected to the internet and required the addition of a hub to enable the provision of grid services from the charger. Participants did not face financial loss, but it should be noted that in all instances the homeowner's broadband connection was used by SMS as the channel to communicate to the technologies in the home. Where batteries were set to discharge electricity in response to a low frequency event, some of this energy was exported from the property, but the duration of such events were short and the cost implications to the participant was insignificant relative to the payment received.

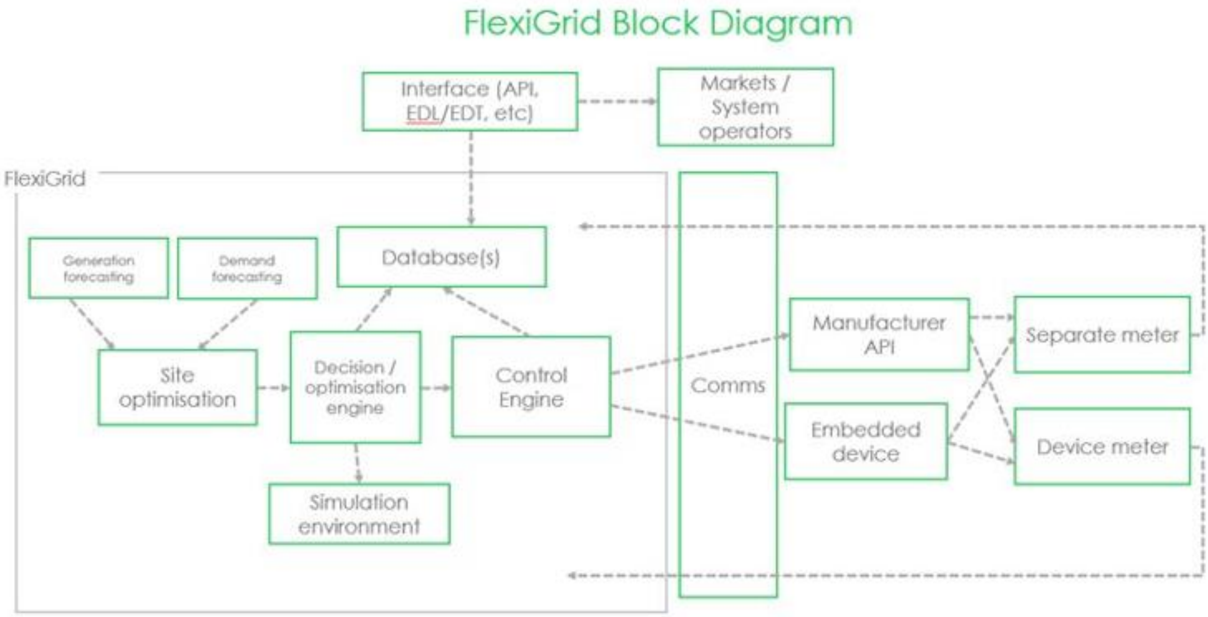


FIGURE 1 BLOCK DIAGRAM OF THE FLEXIGRID ARCHITECTURE USED IN THIS TRIAL

Central to the delivery of grid services from the distributed small-scale assets in the eServe Project was SMS's Virtual Power Plant (VPP), namely FlexiGrid. The primary means for assets to communicate with FlexiGrid is through API's (Application Programming Interface) to the asset manufacturer's own online data platform. The manufacturer's platform in turn communicates to the individual assets over the homeowner's broadband. This route of communications adds dependencies to the control architecture which is why SMS is also working on a local controller which can be deployed alongside assets. The local controller communicates directly with the SMS server through 4G, removing the reliance on the homeowner's broadband and the manufacturer's data platform. FlexiGrid can also ingest multiple other data sources to enable its decision engine to quickly communicate optimal operation settings to the individual assets which it monitors and controls. As part of the delivery of eServe, FlexiGrid has gone through numerous modifications to better enable it to support the delivery of grid services.

During the project delivery, it was decided not to carry out EDIL integration into FlexiGrid. Instead, we implemented a simple text and email-based system for the delivery of forecast information and receipt of dispatch instruction. This decision was reached as it was felt that the EDIL integration was not central to the demonstration but was simply a means of communication. The complexity and time required to deliver EDIL integration didn't justify the outcome, when a more straightforward alternative would deliver the same outcome for the purpose of the trial.

DOMESTIC BATTERIES

FIGURE. 2 EXAMPLE BATTERY INSTALLED IN A DOMESTIC PROPERTY

Domestic battery prices have been decreasing as their uptake has increased globally. In Ireland, government support for PV which is accompanied by batteries and weak export incentives are promoting the proliferation of domestic batteries. The eServe project was able to leverage prior projects to quickly establish a trial group of 19 domestic properties with batteries installed – 9 of which included solar PV. All batteries were of the same model. These batteries each had a power rating of 3.3kW, giving a controllable capacity of 62.7kW. The battery chemistry was Lithium Iron Phosphate and they were warranted for 10 years or 10,000 cycles. Early testing of this battery highlighted that the default software of the system did not allow for the granularity of Frequency measurement required for the trial. As a result, there was a reliance on the manufacturer making changes to their software and updating the relevant appliances in the trial.

CONTROL METHODOLOGY

The batteries were connected to the home-owners broadband which allowed them to communicate with the manufacturer’s servers which in turn communicated to FlexiGrid. The batteries can measure the frequency in the home and can communicate this information centrally. FlexiGrid monitored this frequency and when the measurement went outside predetermined limits, a control action was communicated to each of the assets to ramp up or down their power output as required.

After initial testing and improvements to the VPP and batteries, SMS commenced providing forecasted availability to EirGrid. The forecast information included a 4-hour window with 70% (45kW) of the battery portfolio’s peak controllable load. The initial test was a simulated low frequency event, the results of which are shown in Fig. 3. For this trial there was no need to rely on the frequency measurement at the device level as the instruction to respond was issued by EirGrid. During this first trial, response times were approximately 30 seconds from decision to action implemented, with a max power delivery of 59kW.

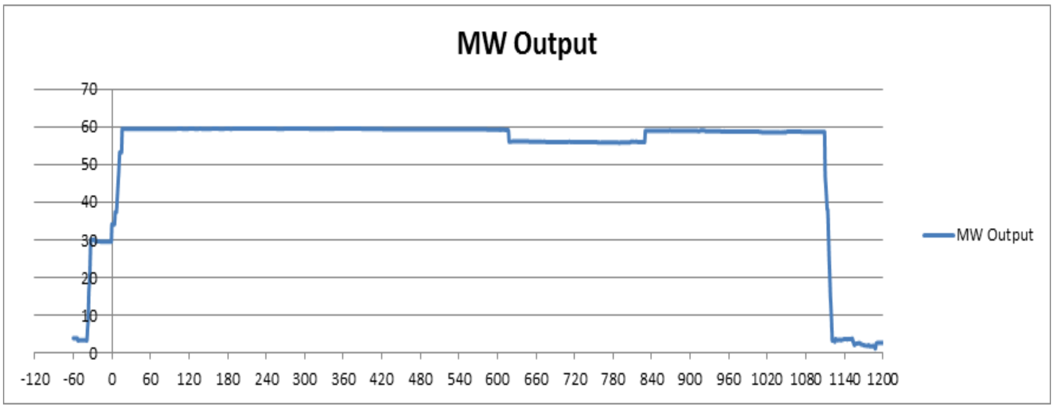


FIG 3. INITIAL TOR2 DELIVERY FROM DOMESTIC BATTERIES

For subsequent testing the batteries were relied upon to identify the grid frequency and FlexiGrid autonomously managed the power level of the assets. To do this, frequency readings were taken from all devices. Due to time delays in the communications, some assets reported frequency faster than others, this was incorporated within our control algorithms. There was also a requirement to implement a series of checks to ensure that the frequency readings which the batteries were responding to were verified (against readings from other devices) before it initiated the control measure to the entire battery portfolio. There was significant variation across the portfolio as highlighted in results to a frequency deviation in Fig.4, but the speed of response was much improved. The refined frequency measurement value used to control the batteries was consistent with grid frequency data supplied directly from EirGrid (Fig.5).

FIG 4. INDIVIDUAL FREQUENCY DATA FROM THE PORTFOLIO OF CONNECTED BATTERIES

FIG. 5 REFINED FREQUENCY MEASUREMENT FROM BATTERIES VS SYSTEM FREQUENCY FROM EIRGRID

After the various iterations and improvement within the battery and our FlexiGrid software, the response time from the battery portfolio was reduced to as low as 1 second from point of frequency deviation. By managing the battery state of charge in advance of the forecasted window, a sustained response from the battery portfolio was delivered as shown in Fig. 6. Whilst 1s response times were achieved using the QTP trial architecture, as shown in Fig. 7 many response times were higher (between 3s and 8s).

FIG.6 BATTERY PORTFOLIO RESPONSE TO FREQUENCY DEVIATION

Battery systems are continuously evolving and improving their application for providing DS3 services. The battery solution which we utilised to demonstrate DS3 services in this trial stores the frequency response characteristic at cloud level. It was shown through the trial (Fig.7) that this configuration will struggle to reliably meet the requirements of the fastest acting DS3 services. The manufacturer of these batteries (as well as others) now offer alternative solutions which are better enabled for frequency service delivery.

Response time following frequency Dip	Batteries responding
1s	5%
2s	32%
3s	63%
4s	89%
8s	95%
No response	1 battery

FIG. 7 RESPONSE TIME FROM 19 BATTERIES TO FREQUENCY DIP BELOW 49.8HZ

As a comparison to the above architecture, a test was set up with a different battery configuration in which the frequency response profile is stored locally on the battery. This system showed that it is possible to remotely set a frequency response characteristic directly on the inverter. As expected, the response time was reliably much lower at approximately 1 second (Fig. 8).

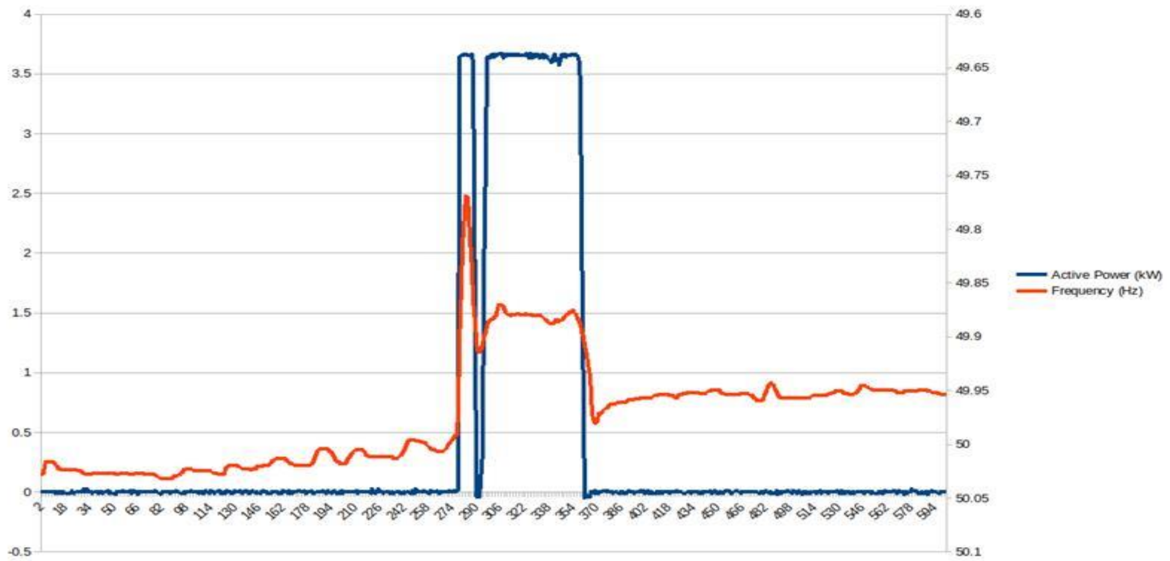


FIG.8 RESPONSE FROM ALTERNATIVE BATTERY TO FREQUENCY DEVIATION IN NOVEMBER

LEARNING OUTCOMES

1. In this trial, the battery and control architecture were comfortably able to deliver Secondary Operating Reserve and slower acting system services. Whilst there are many practical factors to contend with to ensure reliable delivery, proper management of a portfolio of distributed residential batteries will facilitate delivery of these services.

2. The battery and control architecture used in this trial was not able to reliably delivery Fast frequency Response (FFR) or Primary Operating Reserve (POR). However, the trial was able to show that using an alternative control architecture – one making use of local control of the batteries - makes it possible to delivery FFR and POR from residential batteries. Again, proper management of a portfolio of batteries is required is required to ensure the expected level of response is delivered.

3. The trial didn't focus on the incentive required to gain support from participants to allow their devices to be used to provide grid services. Future trials should investigate the incentives required.

4. Battery technology already deployed can, to some extent, be upgraded via remote software upgrades. This puts the emphasis on ensuring that the hardware going into properties today is specified to meet the future requirements of grid service delivery.

5. Hybrid inverters (single inverter for battery and co-located PV) can limit the power output available from batteries during a low frequency event. For example, if there is 1 kW of solar PV generation the battery will only discharge by 2.3 kW, giving the total 3.3 kW inverter output. This reduces available response power from batteries and it also makes the available power dependent on PV generation at that time the response is called for. This may not happen with all hybrid inverters but was a learning from the technology trialled in this project.

6. The system architecture implemented for the 19 batteries systems include numerous external dependencies which would need to be factored into availability forecasting. This includes dependence on the homeowner's broadband, the manufacturers API's and aggregators service availability. There are alternative architectures such as embedding a 4G controller, that can communicate directly with the aggregator, in the battery which would reduce these external dependencies and would likely lead to increased availability.

7. Storing the response setting on individual appliances enables a more consistent fast response time. The frequency response profile stored locally on the inverter of the battery system was capable of sub-second response to frequency deviations. Making decisions centrally and communicating these inserts a variable delay from communications channels as demonstrated by Fig. 4 and Fig. 7.

EV CHARGERS

SMART EV CHARGER

A single smart EV charger type (Fig. 9) was chosen early in the project to limit additional integration work. This charger was a single-phase AC charger with a maximum power usage of 7kW. Having reviewed various smart EV chargers, this model was chosen due to its popularity, meaning that there were many in existence and the base technology was more mature than many others in the industry. The charger chosen includes additional user functionality including an app, to allow users to schedule the chargers or to set the EV charger to make maximum use of any onsite generation. This charger can locally measure frequency and store set points to respond to frequency deviations, giving it advantages for delivering grid services. Finally, the EV charger manufacturer was willing to contribute time to the project to enable FlexiGrid to integrate to their chargers and examine their ability to provide grid services.

FIG. 9 SMART EV CHARGER TECHNOLOGY USED FOR THE TRIAL

VEHICLE-TO-GRID (V2G) CHARGER

When starting this project, there was only a small number of manufacturers making bi-directional EV chargers suitable for domestic properties. Even those that were, the technology was not mature. There was also the issue of the unit cost of a V2G charger in comparison to a standard smart EV charger – the V2G units could cost 5 times more. This limited the uptake of these charger types in homes around Ireland. Another limitation in uptake was the fact that the majority of EV manufacturers did not offer V2G functionality on their cars, except Nissan whose Leaf and eNV200 van were compatible. The unit SMS procured for this trial was a 10kW bidirectional DC charger. The model chosen was not capable of meeting necessary grid protection settings, hence it required an additional protection device to be installed with the charger to allow it to be connected to the grid.

FIG. 10. V2G CHARGER INSTALLED AT SMS'S OFFICE

CONTROL METHODOLOGY

The Smart EV chargers were connected wirelessly to an in-home hub which in turn was connected to the home broadband router. This allowed the EV charger to communicate with the manufacturer's servers which in turn were connected to the FlexiGrid platform through API's. The charger type we used also had a CT clamp which fitted around the main incomer to the property to identify any excess onsite generation. This communications channel allowed SMS to view the devices frequency readings (Fig.11) and set frequency response limits, with two decimal places, which were then saved locally on the EV charger. The frequency response limits informed the charger when to activate a response and when to stop the response, on both the high and low frequency sides.

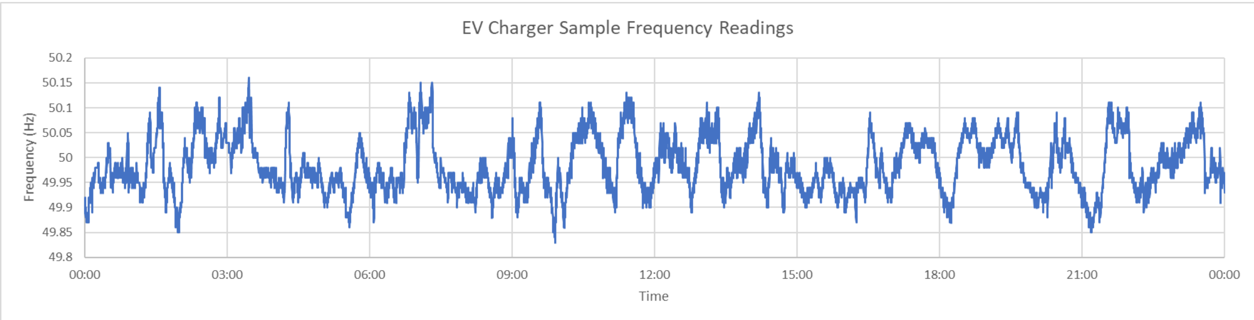


FIG. 11 FREQUENCY READING FROM TRIAL EV CHARGER

To help recover a low frequency, the EV charger is required to remove demand from the system as it is unable to add generation. With a Type 2 EV charger the lowest available power output setting was circa 1.4kW. As part of controlling the chargers, charge was only reduced to the minimum and the charger was not switched off. The maximum charge power for this charger is 7kW giving a maximum contribution per charger of 5.6kW. In reality, the charge power is limited by what power the vehicle can accept. For instance, the 2015-2018 Nissan Leaf had a max charging rate of only 3.3kW (AC), hence if this model of car was charging, the max response that could be delivered from the charger was 1.9kW.

On the opposite end, it is more difficult to provide high frequency response from EV chargers, as this requires limiting the charge to the vehicles for the chance that the reserved power is required to deliver a grid service. There are cases where high frequency service could be offered without the intentional limiting of the charge, for instance the end user may have set the charger to charge only from excess PV, which can result charging headroom. This headroom could be utilised in the event of a high frequency event.

The state of charge (SOC) of the battery in the EV is an important data point in knowing how long the EV needs to charge. However, this data point is not communicated to the smart charger, hence the aggregator is somewhat blind as to how long the charge session will last. It is possible to determine the SoC when the battery is at the latter stages of charging, as the power taken reduces. Since completing this trial SMS have started examining the use of vehicle telematics systems to extract the SoC directly from the vehicle, so FlexiGrid is better informed on the potential capacity of the assets connected.

The impacts of COVID 19 and the necessary travel restrictions impacted the routines of the participants, as a result there was no consistency in the charging levels required by the vehicles. This made it difficult to forecast what EV would be charging at what time during the day and for how long they would be charging. Customers typically had the chargers set up to charge during off peak hours (Fig. 12). However, the EV's were not always plugged in when at home. The boost function meant that the chargers scheduled to charge during the night could receive the majority of the energy during the daytime.

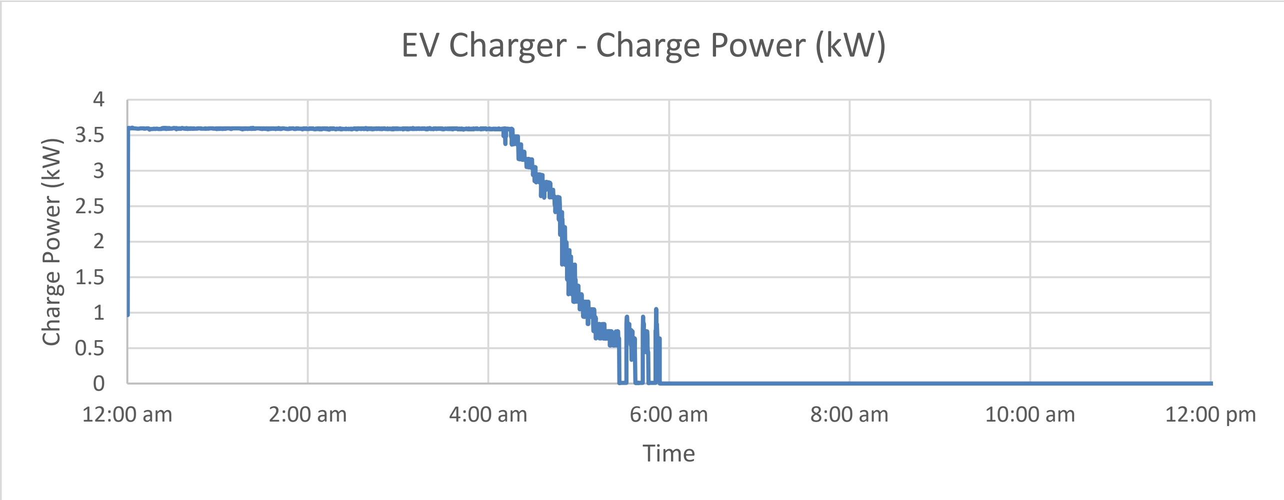


FIG.12 SAMPLE OFF-PEAK CHARGE ROUTINE OF A SMART EV CHARGER

During the period that the 10 EV chargers in the trial were configured to respond to frequency deviations below 49.8Hz there was no observed overlap of frequency disturbance and active charging of an EV. As a result, trials were carried out with the chargers, where the frequency thresholds were set abnormally tight to force a response from the EV chargers. Fig. 13 shows the results of this testing and demonstrates that the EV chargers can deliver frequency response services for both high and low frequency events.

FIG.13 REPONSES FROM SMART EV CHARGER TO FREQUENCY MOVEMENTS

In contrast to the smart EV charger, the V2G charger required the development of a physical control module which needed to be fitted inside the charger. The control module acted as the interface between FlexiGrid and the V2G charger. The module was connected to FlexiGrid over a 4G connection and it could store the frequency response settings locally at the device. This removed some of the dependencies on the communications channels. During the project difficulties were encountered in completing the integration of this control module to the V2G charger which ultimately led to no service delivery from the V2G charger being possible in the trial.

LEARNING & OUTCOMES

1. When it came to recruitment, the eServe Project benefited greatly from early adopters who had an interest in participating. While the financial incentives for participation was strong, the technical nature of the service being provided did limit engagement.

2. A partnership approach was key to the delivery of services from EV chargers. This enabled each partner to use their expertise as part of the service delivery. It also enabled the simple flow of value to the participant through a credit rebate on their bill.

3. As EV charger functionality expands so too does the complexity of delivering grid services from them. An example being the ability to set the charger to maximise the use of excess PV to charge the vehicle. This adds another variable to the efforts to forecast the availability of EVs for providing grid services.

4. The architecture used to connect EV chargers in this project included many dependencies for grid service delivery, such as EV Battery management system, EV chargers, Hub-to-charger wireless connection, in home broadband connection, manufacturers platform and VPP platform. One means of lessening dependencies is with the inclusion of the local controller to allow the charger to directly communicate with the VPP platform.

5. The connectivity to smart EV chargers allows retrospective firmware updates to facilitate grid service delivery. However, with the significant number of electric vehicles and subsequently the number EV chargers that are expected to be deployed in Ireland between now and 2030 (c. 900k), it is important that the hardware is suitable for service delivery. This primarily relates to the accuracy and resolution of in-built metering required for the delivery and verification of service delivery. Early guidance in this space could allow the significant power associated with those chargers be controlled to the benefit of the grid.

6. Discharging power from the EV battery through bi-directional chargers requires approval from the EV manufacturer so as not to invalidate the vehicles warranty agreement. The benefits of V2G are clear, i.e. the ability to gain the same benefit from the EV battery as you would with a stationary battery. However, at the time the project was conducted this was difficult to practically deliver. Hence this area which needs greater collaboration between, EV manufacturers, V2G manufacturers and aggregators.

9. TELECOMMUNICATIONS TRIAL OVERVIEW

BACKGROUND TO CHANGES IN TELECOMMUNICATIONS

Due to the increasing use of renewable energy sources (RES), TSOs worldwide are seeing a shift from operating a centralised portfolio of large, conventional fossil-fuel generators to a more widely distributed network of small-scale RES generation. The current communication method was designed for larger generators, which has resulted in a communication solution that may be inflexible or expensive for distributed energy resources or small-scale System Service providers on the system.

The TSOs current standard communications method is enabled using a Remote Terminal Unit (RTU) located at site, using IEC 60870-5-101 protocol over a serial point-to-point communications channel. The signals themselves are hardwired on-site back to the RTU using various interface points. In some instances, signals travel long distances before reaching their destination. Signals are then converted and transmitted back via an RTU to the TSOs data centres.

This method of collecting data has served SONI and EirGrid well over the years; however, it comes with an overhead. Additional equipment and cabling is required in the server room and telecoms room within our data centres to convert from serial to Internet Protocol (IP) and then connect to Front-End Processors (FEP). Hardwiring at each site requires a considerable number of person hours by our Telecoms Services Providers. When a small number of large generators were connected to the transmission system the serial method, with hardwiring, met our needs. However, where the TSOs are required to exchange data with generators as small as 1 MW, and many different types of generators and system services providers need to be accommodated, this method can be unwieldy. As a result of these changes to the system, the communications network needs to adapt and become more flexible to support these shifting requirements.

The main objective of the trials was to investigate an alternative approach to two-way communication between a distributed energy resource and the TSOs. At present, System Service providers generally use a standard RTU interface device and IEC 60870-5-101 protocol to exchange data with the TSOs. Through allowing new communication methods (and hardware and protocols), it could allow for more effective cost management for small scale projects and could reduce complexity which will facilitate new technologies to connect to the grid.

ENERGIA TRIAL

The Energia trial was intended to investigate a new design in data exchange for the TSOs and Energia. The principle was to trial the direct connection of a Siemens PLC[4] unit owned and operated by Energia, using a protocol-based connection into a TSO gateway device. This protocol-based connection would provide all the required data for the trial without the use of any additional hardwired connections. The gateway device would then communicate back to the control centre over IEC 60870-5-104. This would give the opportunity to trial a protocol and also new equipment on the TSO side. It would also give the opportunity to examine how a protocol-based connection could be implemented.

Fundamentally, the system would comprise a Siemens PLC unit which is controlled and operated by Energia connected to a Schneider gateway device. The connection from the Siemens PLC to the gateway device would be connected over an Ethernet cable between two buildings. It was intended that the TSO equipment would be located in a secure location. The trial was intended to demonstrate the use of a protocol-based connection into customer equipment and potentially the use of authentication and encryption of data.

Data would be exchanged between the TSO data centre and the Cornavarrow wind farm over the internet using a Virtual Private Network (VPN). An overview of the proposed design can be seen in Figure 1 below which shows the connection back to the TSO data centre. A more detailed design of the Cornavarrow wind farm site can be seen on the right

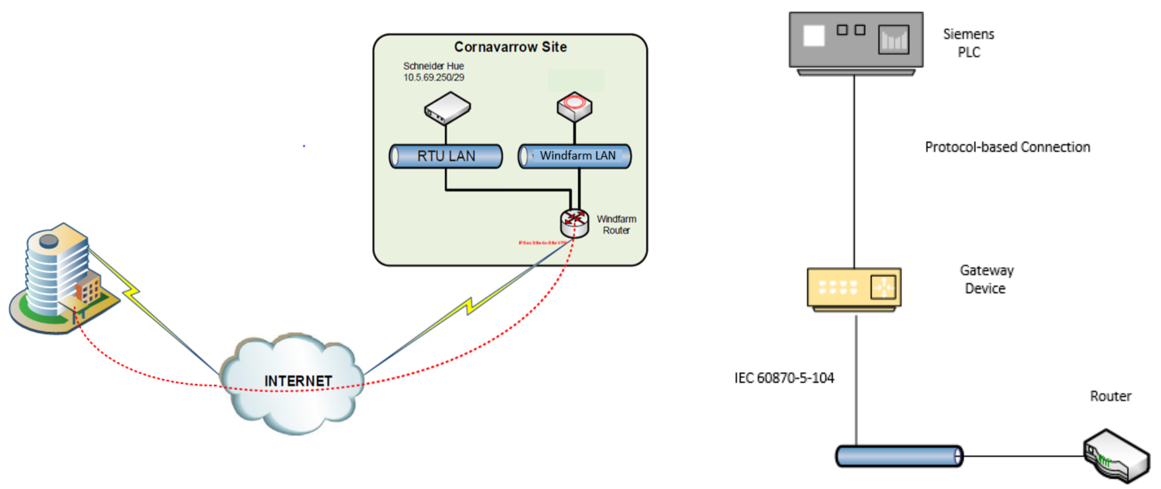


FIGURE 1 SYSTEM OVERVIEW OF ENERGIA TRIAL

4 Programmable Logic Controller

VIOTAS TRIAL

VIOTAS presented a solution for QTP that incorporated redundant cloud-based servers connected across the internet to the TSO data centre. Figure 2 presents an overview of the proposed architecture which could be used to connect various devices and interfaces to the TSOs by using a Virtual RTU. The Virtual RTU would provide the ability to monitor and control signals to and from several different connections with the possibility of connecting with different protocols. No TSO equipment would be installed at the VIOTAS site so the connection would terminate directly into VIOTAS equipment located at their offices in Castletroy, Co. Limerick. This would be a trial from the current operating model of the TSOs, where it is expected that TSO-controlled equipment onsite would provide isolation and connectivity back to the relevant TSO.

As per the TSOs "Telecommunications Protocol Evaluation", it was agreed that Distribute Network Protocol 3 (DNP3) should be trialled due to the benefits it could provide if a trial was to be successful. It was then agreed to implement DNP3 as part of the trial with VIOTAS. DNP3 was to be implemented between the TSO data centre and the Virtual RTU, utilising the TCP/IP capabilities of the protocol. Although DNP3 would be trialled initially, there was an option to possibly trial other protocols with this design. The design could be implemented to connect the Virtual RTU to embedded generation to facilitate various protocols. To the right of Figure 2 below is a high-level concept of the intended design.

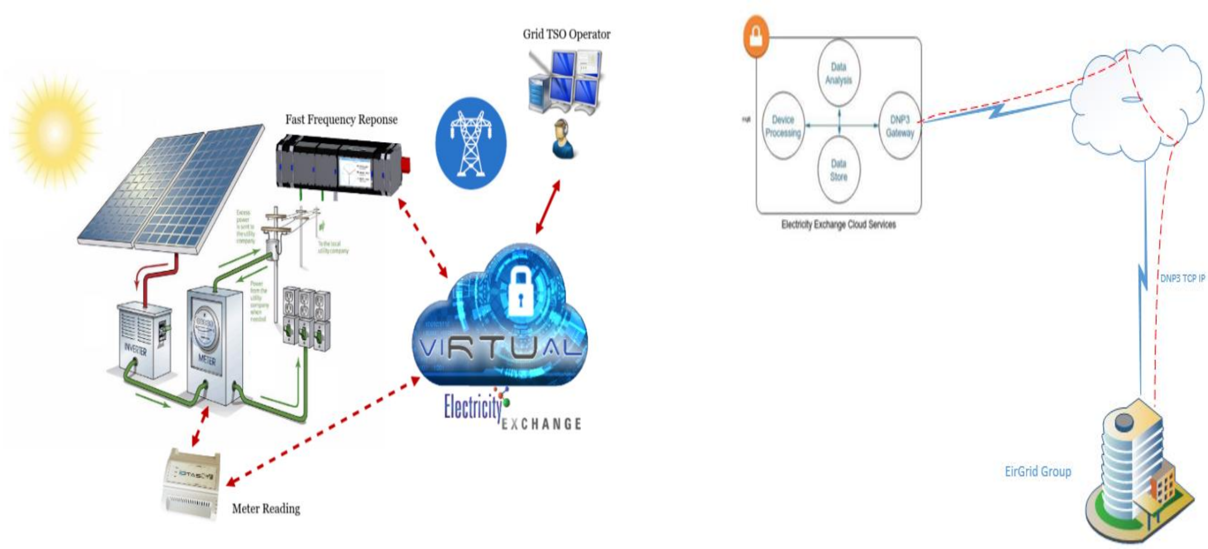


FIGURE 2 OVERVIEW OF THE PROPOSED ARCHITECTURE WHICH COULD BE USED TO CONNECT VARIOUS DEVICES AND INTERFACES TO THE GRID OPERATOR BY USING A VIRTUAL RTU.

SUCCESS CRITERIA

The Table 1 below provides an overview of the success criteria for the telecommunications trials as established at the start of the trial and the TSOs assessment of the achieved status. A breakdown of the key lessons learned are outlined below.

TABLE 1 TRIAL SUCCESS CRITERIA AND THE ACHIEVED STATUS

Success Criteria of Telecommunication Trials	**Outcome**
Project team have a clear understanding of the effort required to implement the selected hardware.	
Project team understand the requirements to support the connection and whether there would be challenges with the connection being replicable.	
A clear understanding of any advantages and disadvantages of implementing the selected protocol.	
A fully functional test environment has been set up within the TSOs for the proposed protocol.	

TELECOMMUNICATIONS TRIAL LEARNINGS

The TSOs acknowledges that whilst the trials did not fully deliver on all the success criteria, the trials have identified several operational complexities for the integration of alternative telecommunications protocols. The following section of the report details the learnings from both a project and technical perspective.

PROJECT LEARNINGS

The first key area is in the project initiation and design phase. A key learning in this area relates to the design and implementation of agile frameworks to progress the trials from concept to delivery. The TSOs recognise the need for greater clarity in the trial design requirements to meet the needs of network security. It should be noted that both trial participants were open to discussions on the designs in order to progress the projects. However, due to the timings when the trials took place, minimal changes could be accommodated due to restricted access to site and other business priorities.

Flexibility	Overall, the trials lacked flexibility and when obstacles were met it was difficult to re-align both projects. The initial designs were ambitious however, it was believed that lessons learned could be captured even if the trial outcomes had to be re-evaluated.
Equipment	The TSOs did not have sufficient oversight over the participant's equipment selections. Some equipment was already purchased prior to detailed technical discussions being held. This meant that some technical limitations existed. For future similar trials, equipment technical requirements should be clearly laid out and agreed in advance of the trial initiation. This will ensure that the trial is capable of delivering on all targets.
Initial Trial Design	Incorporating the proposed solutions / designs by the trial participants in the tender evaluation process, would have facilitated an earlier stage engagement and the TSOs having more input into initial design. VIOTAS and Energia were open to discussions on the designs in order to progress the projects; however, due to the mature stage of the designs it was more challenging to incorporate TSOs feedback.

TECHNICAL LEARNINGS

Although several issues and project constraints limited the implementation of the end- to-end telecommunications within the trials, learnings can be taken from both trials which will inform decisions on architecture and design into the future. At the early stages of these trials, the TSOs were undecided on what protocol would best suit the needs and requirements of the TSOs. Hence, it was decided to trial more than one protocol as part of QTP. The decision was taken to trial IEC 60870-5-104 and DNP3 IP protocols as it was assumed that one or both protocols would be used into the future based on the outcome of the protocol analysis that was completed.

Method of connecting end-to-end	Both trials were to be conducted over the internet using a public carrier. This added security concerns, which ultimately limited the achievement of all the objectives of the trials. However, understanding this restriction in the context of an ever-changing cyber security landscape is a key learning.
Protocol	During the trials, it emerged that IEC 60870-5-104 was the preferable protocol for the TSOs to use for the foreseeable future. While the options are available to trial several different ways of communicating data, with each different method comes an overhead, and it was found that the added complexity and workload with maintaining numerous different protocols was not sustainable or cost-effective from the TSOs perspective. Expertise should be grown in a small number of protocols and increase our security posture in that area.
Device Location	During the trial, the criticality of equipment location became apparent. There were lessons on locational security criteria, and the importance of a secure, well-managed location for siting equipment is acknowledged.
Collaboration with third parties	The importance of collaboration with all stakeholders at an early stage was highlighted. Requesting support or resources for any trial needs to be done at the outset. This is particularly true if access to third party equipment or infrastructure is required. There can be physical constraints or security implications that need to be understood and managed early in the project.

The Interface Device	The TSOs with the help of trials and various stakeholders e.g. ESBN Telecoms, have been able to identify interface devices for use in several different scenarios. The device used, and the method of installation depends on the location, type and size of the customer connecting.
DNP3	DNP3 IP was the protocol chosen to carry out the VIOTAS trial. It is now understood that the best practice for the TSOs is to support a minimum number of protocols and DNP3 is unlikely to be trialled any further. The TSOs will utilise the IEC 60870-5-104 protocol.
Process	Both trials gave a good insight into the processes that would need to be available for customers who wish to connect using a protocol-based connection. During the trials the TSOs developed an understanding of the security concerns in the IT / Operational Technology (OT) context.
Test Platforms	The advantages of a robust fully functioning Test Platform were clearly realised during the trials – the trialling of new technologies and innovative solutions can be enabled by the use of a test platform and a key learning is that offering to trial the full integration and connection to our production mission-critical systems is no longer considered best practice.
Security Design	Throughout the course of these trials, the cybersecurity landscape has changed for the TSOs. We have seen the EU Network and Information Security directive (the first piece of EU-wide cybersecurity legislation) be transposed into Irish law. One of the responsibilities that the NIS directive places on the state is the application of a set of binding security obligations to Operators of Essential Services (OES). EirGrid must comply with these obligations. These trials sought to investigate more open ways of communicating between electricity system participants (generators and demand side units) and the TSOs. The NIS directive and the increasing cybersecurity threat landscape for OES dictate that network connectivity must be designed to be highly secure. It is a significant challenge to design connectivity solutions that are both open and highly secure. The trials were a useful exercise to challenge the current network and security design. As a result, the TSOs now have a better understanding of what is required to implement such designs. The TSOs current NIS standing is predicated on having a secure network that is tightly controlled. The trials challenged the current network design and it is now more fully understood what would be required to implement such solutions. The goal of the Security Group is to reduce the risk of attack and exposure of the TSOs systems. The TSOs also have a greater understanding of what measures the customer would need to put in place to deliver such a solution.

EVOLVING TELECOMMUNICATIONS

The TSOs completed a Telecommunications Strategy document in 2018 which laid out the trajectory of telecommunications for the next five years. Due to several factors, some of which are listed below, it was necessary to update the Telecommunications Strategy ahead of its due date of 2023 in order to reflect the changing landscape. Some of the key events informing this Strategy which have occurred or come into effect since the publication of the 2018 report are as follows:

- There is greater clarity on climate action targets for 2030. These targets will result in a significant increase in distributed energy resources connecting to the power system;
- The Covid-19 pandemic has profoundly changed the way people work including those working in 24/7 Operational Control;
- The NIS Directive is now in force bringing changes within the TSOs and to vendor relationships;
- An upcoming EU Network Code on cyber security will bring more stringent compliance requirements.

PREFERRED PROTOCOL

In 2018, the TSOs were aware of several telecommunication protocols potentially suitable for the utility sector. A technical evaluation was conducted by an independent third party to examine the most suitable options available to the TSOs. During this evaluation, a holistic view of all potentially suitable protocols was conducted. It was concluded in this evaluation that IEC 60870-5-104 and DNP-3 should both be examined and considered as possible options for the future. In 2021, the TSOs updated their Telecommunications Strategy and at this point it is clear the recommendation is that the TSOs should adopt a measured approach and reduce the number of telecommunications protocols to a minimum. While it is important to keep an open mind into the future, the most suitable protocol for the TSOs is currently IEC 60870-5-104.

SECURITY

In 2018, cyber security played a significant role in the development of our Telecommunications Strategy. The strategy proposes the development of a robust cyber security plan and places significant importance on OT Security. Between 2018 and 2021 when the TSOs most recently updated their Telecommunications Strategy, there has been significant change within the cyber security landscape. The NIS Directive brought tighter regulation and ENTSO-e Network Codes brought more stringent compliance requirements. These requirements along with an existing responsibility to secure the mission-critical systems means that all new connectivity types for OT traffic need to be assessed in the context of the overall OT Security best practice, and not simply the possibilities of the technology.

DEVICES

In the 2018 TSOs Telecommunications Strategy, it was assumed that a TSO RTU or similar device would need to be installed in all locations where controllability or data exchange is required on behalf of the TSOs. In the 2021 Telecommunications Strategy, this view is no longer the case, and it is now understood that in certain select scenarios a TSO device is no longer required i.e. ≥ 1 MW and <5MW generators in Ireland. This will result in a simplified design with a reduced amount of equipment and lower cost.

HARDWIRING

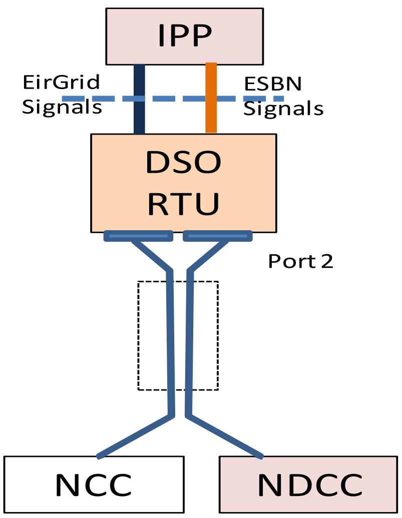
In 2018, the trajectory for the TSOs was to continue with a hardwiring approach whereby each signal would be connected over its own cabling, and physical interface points would be used between the TSOs and the connecting party infrastructure. While this is a very reliable means of connecting signals, it does come with an overhead. In 2021, there is a clear ambition on the behalf of the TSOs to simplify this approach. In collaboration with our DSO partner ESBN, a protocol-based connection between the control system and the RTU device has been trialled. This would initially be implemented successfully in Ireland with 1-5MW generators and a DSO RTU.

TSO/DSO SHARED RTU IRELAND

Historically, a TSO RTU has been installed on all generator sites >5 MW in size to give effect to dispatch and observability to the TSO on any relevant distribution-connected plant. In recent years, with the increase in renewable generation, it was deemed necessary and proportional to extend the dispatch and observability obligations on Power Park Modules (PPM) in Ireland with generation ≥ 1 MW and <5MW. The design being discussed here is relevant for customers ≥ 1 MW and <5MW only.

For customers between 1 MW and 5 MW, the DSO and the TSO ESBN and EirGrid have been committed to reducing costs and simplifying the overall design. Collaborative engagement took place in Ireland between the TSO and DSO to plot a way forward that ultimately led to the signing of a Memorandum of Understanding between both parties. One of the primary principles underpinning this agreement is as follows: in general, and unless specific circumstances dictate otherwise, the TSO and DSO shall collaborate to identify and implement the solution that delivers the required level of functionality at the least overall cost to the customer.

Leading on from this agreement, technical details were discussed and ultimately a trial was conducted to prove the functionality and deliverability of this solution. See Figure 3 below which shows the basic design.



FIGUR 3 TSO/DSO IRELAND SHARED RTU DESIGN OVERVIEW

9.1.1 TECHNOLOGY AND PROTOCOL

- Both the TSO and DSO in Ireland are utilising a single RTU, owned and operated by the DSO, which can deliver functionality for both parties.
- Separate ports on the DSO RTU are being used for the routing of signal data to the TSO and DSO data centres.
- Means are in place to deliver effectively separate telecommunications channels to the TSO and DSO data centres from the DSO RTU. This will be achieved through isolation within the RTU, and separate communication channels back to control centres.
- Initially, the shared RTU is being implemented using hardwiring. However, if the use of a protocol between the PPM and the DSO RTU is agreed with industry, the TSO and DSO will inform the participants of the protocol specifics. This functionality has been trialled by the DSO and TSO in Ireland and both parties are confident going forward it will be used to deliver an effective solution in the case of the shared RTU. Both the TSO and DSO will work collaboratively to implement this design. Cyber security will continue to play a vital role in the delivery of a protocol-based design including robust security measures.

ADDITIONAL LEARNINGS

Over the duration of the QTP, the TSOs have conducted several trials in collaboration with various stakeholders and third parties. The aggregated learnings from these trials will help guide the TSOs Telecommunications Strategy into the future. Below, in Figure 4, is a typical scenario that could be used to connect a PPM to the TSO. With the help of the trials, the TSOs have developed a clearer understanding of suitable solutions available, and how they could be implemented. These findings can help steer our course towards a more efficient telecommunications network. While security concerns are still a significant challenge for TSOs worldwide, it is fully understood that this work needs to be carried out in collaboration with our security partners and the broader industry to help deliver suitable solutions. While we will continue to support the IEC 60870-5-101 protocol, it is evident that a move to IEC 60870-5-104 could bring significant benefits to the TSOs and ultimately lead to a better solution for all.

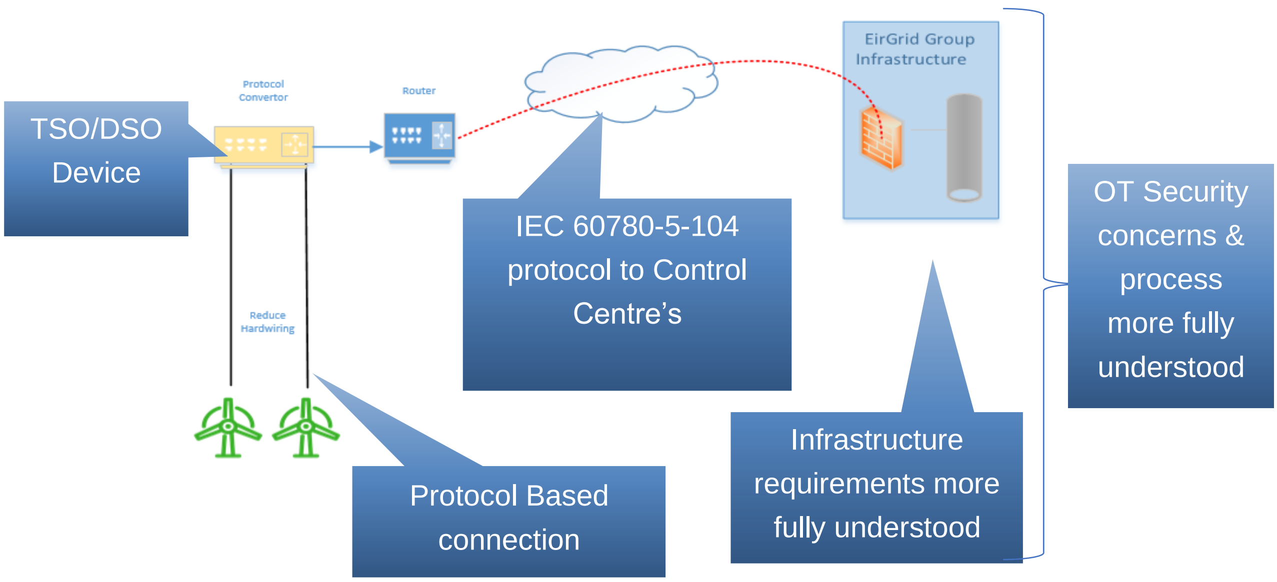


FIGURE 4 TYPICAL SCENARIO THAT COULD BE USED TO CONNECT A PPM TO THE TSOS

KEY LEARNINGS AND OUTCOMES

The TSOs would like to thank VIOTAS and Energia for their support during the telecommunications trials. Trials such as these are very important for the TSOs to help understand the roadmap for telecommunications into the future. Both Energia and VIOTAS brought forward new solution designs that have helped the TSOs look at the possibilities of telecommunications. Without the assistance of industry, the TSOs would not have been able to reach the learnings and outcomes included.

The following section of the report presents the key learnings and outcomes of the trials. The trials with Energia and VIOTAS were not fully completed. Significant lessons have been learned throughout the course of the trials (as set out in the table below) and it was therefore, deemed an appropriate time by the TSOs to terminate the trials. The key findings would then be used to develop a roadmap for telecommunications between the distributed energy resource (DER) and the TSOs.

In addition, further learnings have been incorporated from other work that was undertaken during the trials duration. Over the duration of the trial the TSOs engaged independent consultants to conduct a Telecommunications Protocol and Technical Evaluation. EirGrid in partnership with ESBN has also completed the work on the sharing of TSO/DSO RTUs in Ireland between ESBN and EirGrid.
As a result of the combination of the trials and other projects, the TSOs have been able to advance the position on future telecommunications technology and help establish a clearer roadmap. This roadmap will help to deliver a suitable telecommunications solution for distributed energy resources that would reduce costs, complexity and ultimately make it easier for participants to exchange data with the TSOs.

COMMUNICATION TO CONTROL CENTRES

Currently, IEC 60870-5-101 is used to communicate the majority of data between the TSOs control centres and the numerous connections dispersed throughout the networks. In order to overcome the various challenges that serial connections pose while also taking into account the findings from various trials, the TSOs will drive the delivery of IEC 60870-5-104 for data exchange to and from control centres. This will help ensure the secure monitoring of new connections onto the grid. The continued migration onto a Multiprotocol Label Switching (MPLS) network will allow for greater scalability and performance and ultimately a better user experience for all. The goal is to reach a point where the end-to-end telecommunications are standardised.

PROTOCOL-BASED CONNECTIONS

Traditionally, hardwired connections have been the primary method used to collect data from distributed energy resources. However, it is now understood that a protocol-based connection can deliver this functionality reliably, which would mean reduced complexity and costs. The initial implementation of this type of design would be on a connecting party between 1 MW to 5 MW using the shared DSO RTU in Ireland. Assuming controllability is proven successfully on these types of connections we can then look to possibly implement this type of solution in other locations, which will depend on the success of the rollout to these connections between 1MW and 5MW.

SHARED RTU IRELAND

The DSO and TSO are committed to reducing costs and complexity for distribution connected plant ≥ 1 MW and <5MW in Ireland, while maintaining the integrity and security of the power system. To facilitate this, the TSO and DSO have agreed to share a single RTU owned and operated by the DSO for all these connection types. This will significantly reduce the number of RTUs required for 1 MW to 5 MW connections. The shared RTU will also remove the need to exchange data between the DSO and the TSO using the Secure Inter-Control Centre Protocol Communications link (SICCP) in Ireland on these connections. This will further reduce complexity within the overall design. The shared RTU agreement is now in operation and is being implemented on all new connections of this scale that are required to be controllable in the future in Ireland.

TEST PLATFORM

By using the learnings from several trials and with the support of other parties such as ESBN Telecoms, the TSOs have been able to compile a list of specifications and functionality that could be implemented in a progressive test platform. These learnings are essential as we look to the future delivery of telecommunications, and methods of safely testing new connections and data types. The findings related to the test platform, will be analysed further with the possibility of inclusion in future system upgrades. A key learning was that offering to trial the full integration and connection to our production mission-critical systems is no longer considered best practice.

SECURITY

In today's utilities sector, security is paramount, and all new methods of data exchange must be evaluated on a case-by-case basis, with best practises applied, regardless of the technology's functional capability. Using the lessons learned from the various trials, we now have a greater understanding of the protocols and procedures that must be applied in order to move forward with innovative solutions. We can use this knowledge to help implement possible future approaches in a secure manner.

STANDARDISED END TO END TELECOMMUNICATIONS

In order to have a simplified telecommunications design, that is replicable, and can be implemented and maintained in a timely fashion it is essential to develop standards. As part of the telecommunications roadmap, the TSOs will develop requirement specifications with the assistance from the DSO and ESBN Telecoms. In the event the requirement specifications have implications for industry, documentation will be circulated. For example, in the case of a protocol-based connection into the DSO RTU in Ireland, a specification document will be developed by the DSO and the TSO outlining the connectivity principles and testing requirements including site acceptance test and interoperability tests. Therefore, ensuring each connection will be consistent in design with the next.

10. COPYRIGHT

Changes in this document will be notified and approved by the PMB. This document will be approved by the PMB.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under EC-GA No 773505.