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Qualification Trial Process for technology Integration and trialling of System Services

D4.4

EU-SysFlex

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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
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
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 provides details and the outcomes and progress of activities currently being carried out under the EU-SysFlex Qualification Trial Process (QtP) in Ireland and Northern Ireland, T4.3 of the H2020 EU-SysFlex project. The overall deliverable for the programme will be the publication of technical standards and operating protocols for new technologies, which will be completed annually. This includes identifying the appropriate testing and commissioning for the integration of new technologies, signalling requirements and real-time monitoring of service provision, scheduling and forecasting tools to facilitate dispatch in real-time to facilitate the utilisation of non-energy services provider. The QtP brings together many different strands; including facilitating a range of new technologies classes to provide innovative system services.

The Qualification Trial Process (QTP) commenced in March 2017. The trials consisted of fifteen individual technology trials across twelve separate Providing Units. Following the completion of the QtP for 2017, the TSOs have identified twenty six findings. The rationale for each of these findings can be found in Appendix A.

Following the completion of the QtP in 2017, the TSOs have applied a number of the learnings based on the feedback from trial participants. As a result, the TSOs have identified a need to expand on key topics for consideration as part of new technology integration through the QTP across EirGrid and SONI. The purpose of this is to identify commercial and technical considerations for the qualification and large scale deployment of new technologies on the power system for 2030.
For the 2018 Qualification Trial Process, three projects were selected to examine barriers to large scale deployment. The trials focus on three technical considerations network limitations, communication and future barriers for embedded service providers. Building on the 2017 and 2018 trials, two focused workstreams have been identified for further development in 2019. A QtP technology integration forum will be established and new set of qualification trials will take place in 2019.

The technology integration forum, aims to provide a forum to discuss and address issues which may impact the integration of new technology. The forum consists of industry participants from across Ireland & Northern Ireland. This may potentially include representatives from academia and industry across Ireland, Northern Ireland and Europe. Separate technology forums are to be held approximately every four months. A range of technologies will be discussed including storage, solar, demand side management and hybrids. As the forum develops over time, more technology categories will be discussed.

The 2019 Qualification Trial Process will include provenability, distribution impact and standard and compliance trials to demonstrate capability in the reserve, ramping and fast-acting reserve categories. The trials will be designed to be bespoke with a focus on innovative technologies and strategy.

1. INTRODUCTION

1.1 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 many other WP 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.

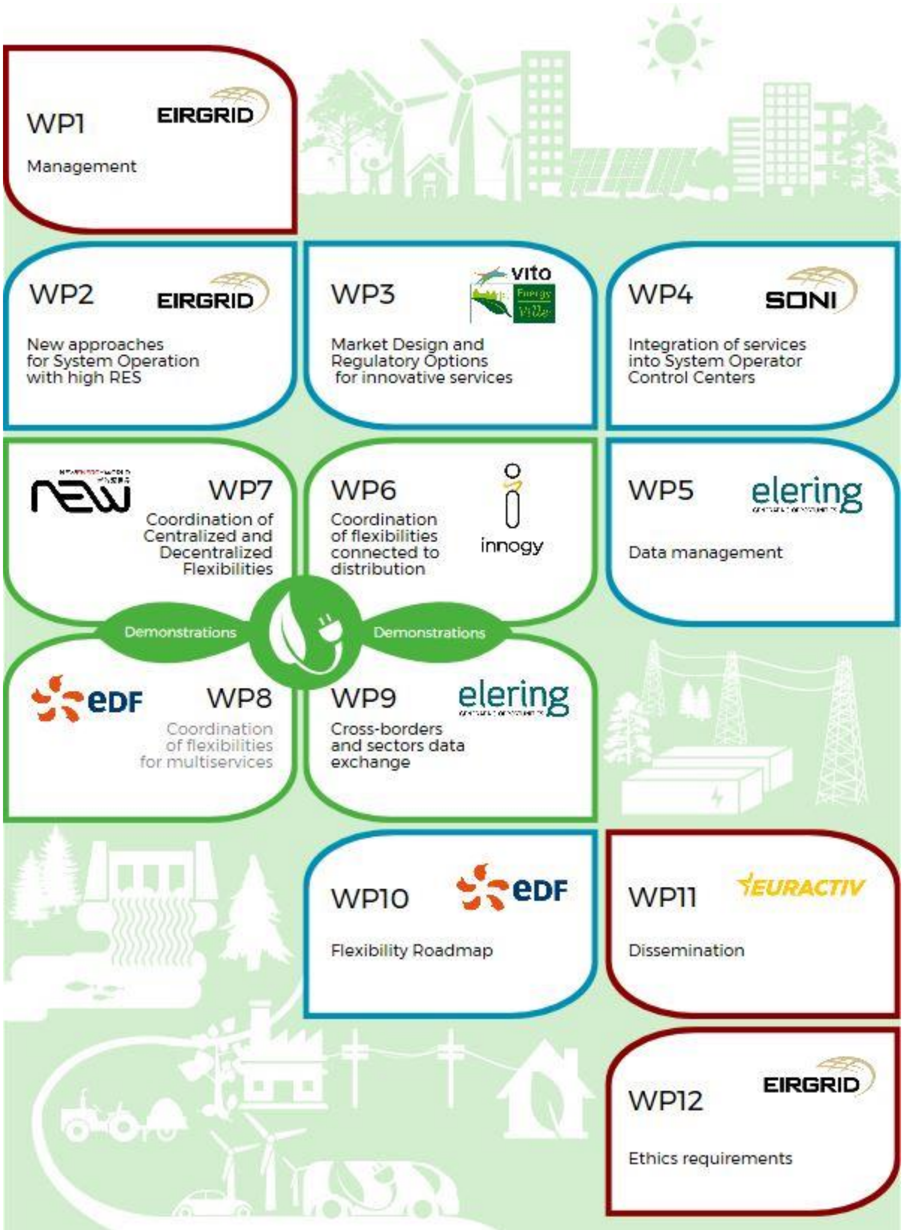

FIGURE 1- EU-SYSFLEX WORK PLAN

1.2 T4.3 WITHIN EU-SYSFLEX

The Qualification Trial Process (QtP) in T4.3 acts as a platform, providing 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 TSO's to meet the objectives of 40% electricity from renewables in Ireland and Northern Ireland by 2020. Today, Ireland & Northern Irelands' power system is the first in the world capable of delivering 65% of instantaneous electricity demand from non-synchronous sources including wind and solar. In 2017, Ireland and Northern Ireland achieved 30% of annual energy consumption from renewable sources.

1.2.1 MAIN CHALLENGES LINKED TO HIGH RES-E PENETRATION

In seeking to meet Ireland and Northern Irelands renewable objectives of 2020, the power system needs to be capable of operating at up to three quarters of the power being delivered from renewable technologies. As we increase the current operational limit of 65% to 75%[1], we have to increasingly rely on new technologies to provide the resilience of the system. Today, Ireland and Northern Ireland are addressing the challenges that Europe will likely see in the near 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 to getting these resilience services from new technologies when no one else in the world is seeing these issues?
- How do you go through this transition without threatening the security of the power system?
- How do you create a route to market to facilitate investment in demonstrations to satisfy technical scarcities?
- How do you do this 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 role 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.

[1] http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/

2. MANAGING THE TRANSITION TO NEW TECHNOLOGIES

Over the past ten years EirGrid and SONI, the Transmission System Operators in Ireland and Northern Ireland respectively, have seen increasing changes in the technology that makes up our electric power system. Today, and in the future, behind the meter technologies such as rooftop solar PV, Battery Storage, Vehicle to Grid Charging and energy management systems are changing the power system. The need for greater transparency of data and information will also drive change across the sector. As renewable generation (wind & solar in Ireland and Northern Ireland), displaces conventional generation on the system, we need system services to come from sources other than conventional generation.

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 reliance on these technologies. This confidence is developed through operational practice, learnings and continual improvement. The TSOs 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 services. In doing so, the TSOs can develop a deep understanding of these 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. The first trial period started in March 2017, specifics of the trial's format for 2017 are described in Section 3.1.

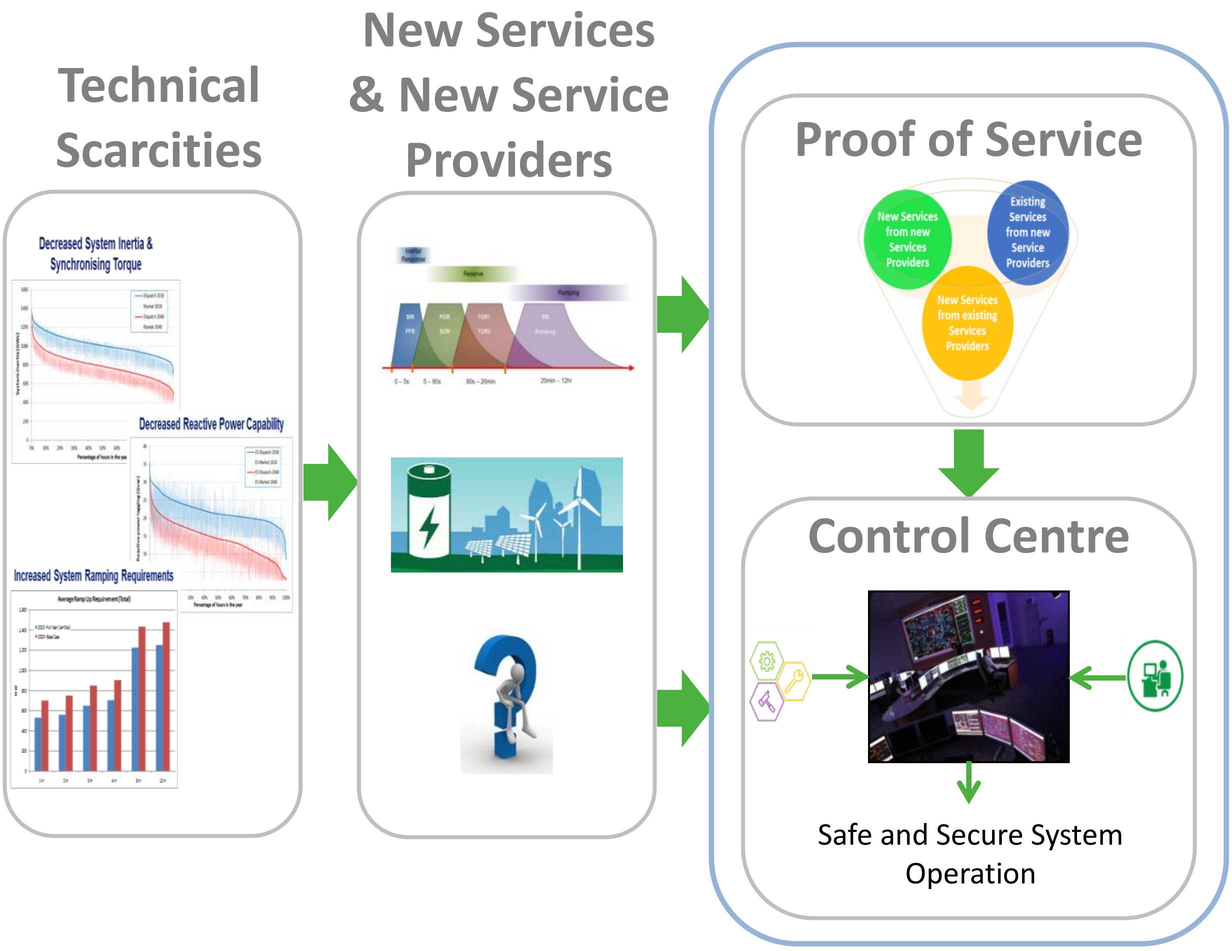

FIGURE 2 – VISUALISATION OF HOW QTP FACILITATES CHANGES IN SYSTEM OPERATION

3.1 TRIAL PRINCIPLES

There are a number of 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 TSOs consider a technology's ability to provide a number of 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, the TSOs 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.

3.2 2017 QUALIFICATION TRIAL PROCESS

The Qualification Trials Process commenced in March 2017. The trials consisted of fifteen individual technology trials across twelve separate providing units. The breakdown of trial technologies is shown in Table 1 below. Eight trial categories were assessed in total.

Provenability			**Measurability**		
DS3 System Service	**Technology Category**	**Participants**	**DS3 System Service**	**Technology Category**	**Participants**
POR	Wind	2	FFR	CDGU	1
POR	Wind (with Emulated Inertia)	3	FFR	Wind	1
POR	DSM	2	FFR	DSM	1
POR	Sync Comp (Energy Storage Unit)	1	FFR	HVDC Interconnector	2
			FPFAPR/DRR	CDGU	1
			FPFAPR/DRR	Wind	1

TABLE 1: LIST OF 2016/17 DS3 QUALIFICATION TRIAL CATEGORIES

The trials ran for 6 months with two core objectives:

1. To identify if the participants technologies could provide a response to an event in line with the DS3 System Services definition of the service they were demonstrating and
2. To identify any operational complexities driven by the provision of 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 DS3 System Services definitions.

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

4. 2017 TRIALLED PRODUCT DESCRIPTIONS

4.1 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.

4.2 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.

4.2.1 FAST POST-FAULT ACTIVE POWER RECOVERY

The Fast Post-Fault Active Power Recovery (FPFAPR) service provides a positive contribution to system security. Fast Post-Fault Active Power Recovery is defined as having been provided when, for any fault disturbance that is cleared within 900ms, a plant that is exporting active power to the system recovers its active power to at least 90% of its pre-fault value within 250ms of the voltage recovering to at least 90% of its pre-fault value. The service provider must remain connected to the system for at least 15 minutes following the fault. The FPFAPR volume in a settlement period is based on MW output during that period.

4.2.2 DYNAMIC REACTIVE RESPONSE

Dynamic Reactive Response (DRR) service is defined as the ability of a unit when connected to deliver a reactive current response for voltage dips in excess of 30% that would achieve at least a reactive power in MVAR of 31% of the registered capacity at nominal voltage. The reactive current response must be supplied with a rise time no greater than 40ms and a settling time no greater than 300ms. The volume is based on the unit's registered capacity when connected and capable of providing the required response. The measurement of this product requires that high quality phasor measurement units be installed at the provider's site with appropriate communication and access arrangements agreed with the TSOs.

5. 2017 TRIAL OUCOMES & LEARNINGS

Following the completion of the QtP for 2017, the TSOs have identified 26 findings. These findings informed the TSOs' decisions relating to system services product design, procurement and contractual arrangements, and other TSO systems and processes. The rationale for each of these findings can be found in the EU-SysFlex Qualification Trials Process Outcomes and Learnings report 2017, which is outlined in Appendix A of this report

These outputs also inform the development and enhancement of the TSOs' systems for performance monitoring, scheduling and settlement of services. As well as, external processes and outputs such as product design decisions, procurement considerations/eligibility and compliance and standards described in the DS3 System Services Protocol document[2].

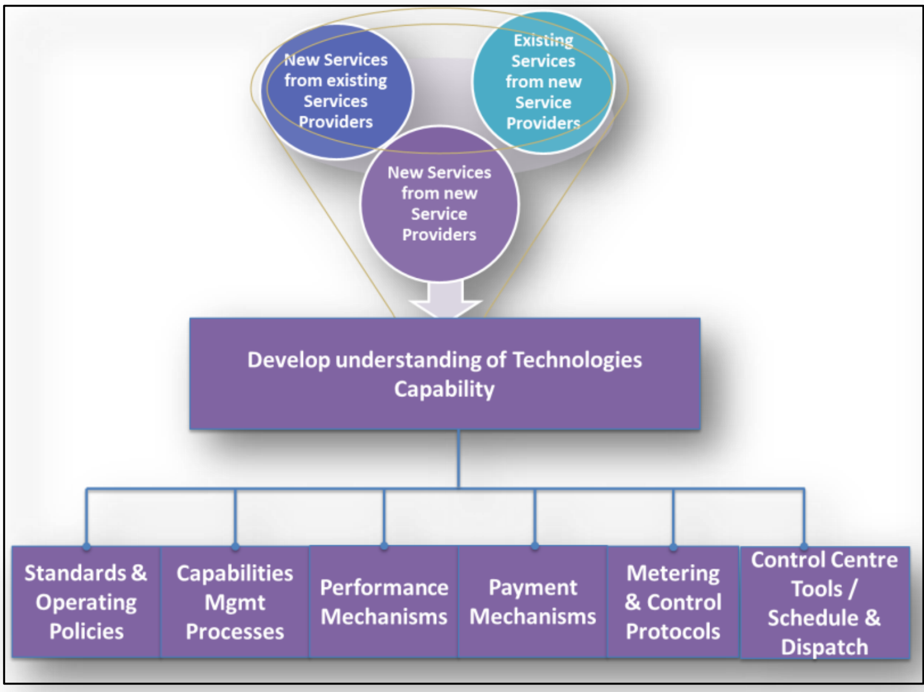

FIGURE 3: GRAPHICAL REPRESENTATION OF DS3 QUALIFICATION TRIAL OBJECTIVES

It is a finding of the 2017 QtP that all technologies participating in the POR and FFR trials should be considered as proven technologies for these services going forward.

It is a finding of the 2017 QtP that all technologies participating in the DRR and FPFAPR trials should not yet be considered as proven for the provision of these services. However, the TSOs propose that alternative approaches will be undertaken to further understand the provision of DRR and FPFAPR in order to determine how various technologies can be deemed proven for these services in advance of the TSO contracting for services. This will likely be based on the evaluation of historical fault record data gathered by the TSOs.

[2] http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-System-Services-Protocol-Regulated-Arrangements_final.pdf

Table 2 provides an overview of the technologies that are now considered to be proven for system services arising from the 2017 QtP. The full list of technologies proven to provide system services is available on the TSO's website[2]. Classification as a proven technology arising from the QtP will inform the TSOs' management of the procurement process for the provision of system services. It does not guarantee that a service provider will receive a contract. This is determined based on the tendering party's technical submission.

As part of the procurement process, the tendering party's ability to adhere to minimum standards relating to testing, compliance and signals installed, which have been identified by this trial process, may be evaluated. Therefore, although a technology class may be considered proven for the provision of a particular service, there may be specific work to be undertaken by individual tenderers in order to be successful in any procurement process.

Technology Class / Sub Class	Services Applicable
Wind - Wind Farm Control	FFR, POR, SOR,TOR1
Wind – Emulated Inertia	FFR,POR
Demand Side Management (DSM)	FFR,POR,SOR,TOR1
Hybrid of a Synchronous Compensator and Flywheel	FFR, POR,SOR,TOR1
Centrally Dispatched Generating Unit (CDGU)	FFR
HVDC Interconnectors	FFR

TABLE 2: TECHNOLOGIES THAT MAY BE DEEMED PROVEN TECHNOLOGIES FOR FUTURE PROCUREMENTS

6. 2017 TRIAL FORMAT AND LEARNINGS

As part of the 2017 overall learnings, trial participants were asked to provide feedback on the format and structure. This feedback, along with the TSOs learnings will help to shape the format and design of future trials. Overall, trial participants fully supported the purpose of the QtP and believed it achieved their overall objectives. However, there were a number of common themes which it was suggested either could be done differently, or perhaps may no longer be appropriate for future trials. These are discussed in detail in the following sections of this report.

6.1 PROCUREMENT AND SELECTION PROCESS

From the TSOs perspective the running of an industry consultation and full procurement process took significant time and resources to deliver. Overall, the proposed format of the trial did not change significantly and some lots within the procurement received no industry submissions. From a trial participant's perspective, the time taken to run these aspects added considerable delay to the desired trial commencement date.

Additionally, given the timing between the procurement process and start of the trials, it was necessary to require as part of the procurement process that any tenderer would need to be connected and operational in advance of the trial commencing. This effectively excluded any technology which is not currently connected and operational on the system in time for the trials to start.

6.2 TRIAL COMMECEMENT

The time between end of procurement and signing of contracts to commencement of trials was one month. This timeline was extremely challenging for all involved and resulted in some trial participants failing to have key deliverables achieved in advance of commencing the trials:

- Real-time signals and controls,
- Measurement Equipment installed and operational, and
- Compliance Testing completed and signed off.

A number of trial participants had significant issues with providing these over the early months of the trial. From a TSOs perspective, this short lead time into the trials left little time to fully understand the operating setup of each participant, develop detailed project plans and agree key milestones and learnings to be achieved.

6.3 TRIAL FORMAT

The format of running fifteen trials in parallel over a pre-defined time had merit as it allowed the TSOs to attempt to prove as many of the larger technology classes as possible in advance of the next procurement process. However in terms of running the trials and the learnings that can be obtained, co-ordinating such large numbers of trials in a short period was very challenging. It is the opinion of the TSOs that each trial should have its own format, timelines, learnings to be achieved and agreed project plan and that these should be based on the contents and complexity of each trial. Where possible future trials should run as an end to end approach where required signals, testing processes and measurement devices and defined and installed in advance of the trials commencement.

6.4 FUTURE SELECTION PROCESS CONSIDERATIONS

Following the 2017 QtP, the TSOs envisage future trial processes may become more focussed on the interaction between transmission and distribution service providers. As a result, the following should be considered for future trials:

1. Greater interactions and coordination with the DSO as majority of trial participants are likely to be connected at distribution level.

2. Provenability trials should continue but are open to all system services.

3. Measurability trials may be amended to become compliance and standards trials. These trials will be open to trial participants whose technology classes are proven but wish to demonstrate novel approaches to current compliance and standards. This could consist of any of the following;
    a. New approaches to measurement of aggregators.
    b. New mechanisms for provision of signals.
    c. Technologies providing services in an inherently different approach.

4. The trial selection criteria should be defined and remain for a number of years to allow units not currently operational the opportunity to partake in future trials.

5. In cases where historical data may already be available to prove a technology class then this should be used as much as possible to identify provenability rather than running bespoke trials.

7. 2018 QUALIFICATION TRIAL PROCESS (QTP)

Following the completion of the QtP in 2017, the TSOs have applied a number of the learning based on the feedback from trial participants. As a result, the TSOs have expanded the scope of the QtP across EirGrid and SONI 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 2018, three projects were selected to examine these barriers. The trials focus on three technical considerations network, communication and future barriers.

Trial 1 – Residential Service Provision (Power Off & Save): This pilot project, aims to investigate if a test group of 1,500 residential consumers can significantly reduce their consumption on request for approximately 30 minutes to allow the TSO to manage the grid at peak times. The trials main focus is to identify the potential for flexibility services at scale based on the actual trial information. Both the technical and behavioural learnings are included in this report. The outcomes of the trial form the basis for identifying key areas for future trials to develop solution for an enhanced portfolio of service providers.

Trial 2 – Steady State Reactive Power (SSRP): In Ireland and Northern Ireland, the need for Steady State Reactive Power (SSRP) from new sources has been identified. However, due to a number of network limitations type B windfarms are currently not capable of providing this service. As a result, the TSOs in Ireland and Northern Ireland have developed separate projects to investigate solutions to acquire services from these potential service providers.

Trial 3 – Control and Signals trial: The main purpose of the trial is to develop an alternative mechanism to the TSOs current communication protocol. The need for this has been identified due to the cost element associated with the telecommunication protocols to enable two-way communication between the generator and the network operator. When compared to a conventional generator, particularly where multiple small sources are providing the service. As a result, there is a need for network operators to re-evaluate the protocols to support the advances in technology. By implementing a new communication protocols and standards the cost to enter the service market could potentially reduce. This has the potential to remove barriers for new technology to participate in a service market.

8. RESIDENTIAL DEMAND SIDE MANAGEMENT – PILOT PROJECT

8.1 TRIAL OVERVIEW

The integration of Demand Side Management (DSM) is an important component of tomorrow's power system, particularly in situations of high integration of renewables, where conventional fossil-fuel is displaced. Ireland and Northern Ireland is a small island with ambitious targets for renewable generation and increased energy user participation. Such developments create opportunities to do things differently and deliver solutions that have tangible benefits for customers and the wider community.

The pilot project Power Off and Save (POAS) has shown that residential homes are potentially capable of contributing to providing greater flexibility in moving towards a decentralised power system. Over the last 18 months consumers have shown they are willing to give over control of their energy consumption and not feel an impact on their standard of living.

8.2 BACKGROUND TO THE RESIDENTIAL CONSUMER DEMAND RESPONSE SCHEME

In 2011, a decision paper published by the Commission for Energy Regulation (CER) depicted a vision for DSM in Ireland by 2020. This vision outlines the potential for DSM participation to evolve to a larger scale beyond 2020, encompassing participants of all demand types, including at the residential level. The integration of DSM is an important component of the European Union's transition towards a low carbon economy. It is expected to feature as a key part of the energy system up to 2030. The European Network of Transmission System Operators - electricity (ENTSO-e), view Demand Side Response (DSR) as a key component in the successful evolution of the power system, with significant contributions from intermittent sources of generation and power intensive loads[3]. In Ireland DSM has experienced rapid growth in recent times, but this has mainly been focused on commercial and industrial loads. It is estimated 25% of the total demand is made up of residential consumers. This has the potential to provide real benefits from capturing the value of residential DSM.

The potential benefits of DSM are:

- **Power System** – potential for greater accommodation of intermittent renewables, enhanced generation adequacy, reduced system/consumption costs and potential for avoided / deferred network investment.
- **Consumer** – reduced bills, greater management of the energy they produce and consume.

[3] https://docstore.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/entsoe_pp_dsr_web.pdf

8.3 OBJECTIVES OF POWER OFF AND SAVE

The primary objective of POAS was to establish and operate a residential, consumer-based demand response project. POAS has engaged with over 1,400 residential homes over a 2-year period, with participants asked to reduce their electricity consumption for 30 minutes on 10 separate occasions through both manual and automated means.

The project was tasked with gaining understandings into the potential for full-scale Demand Side Management (DSM) in the home with conclusions used to determine how residential DSM can be best utilised in future energy market arrangements. In addition, a central principle of the scheme during its implementation was that the comfort level of residential consumers shall not be adversely affected.

<u>The high level objectives for this project were:</u>

- Establish and operate a residential consumer-based demand response project, recruiting and engaging the targeted number of customers.
- Operate the scheme with no adverse effects on the comfort of the consumer in their home due to their involvement in the scheme.
- Utilise a range of smart home technology types in the home with accurate measurement capability to determine the capability of residential customers to provide demand response and potentially DS3 System Services.
- Investigate how to incentivise customers to take part in the demand response events
- Investigate consumers' attitudes to such a scheme and their willingness to participate in demand response events.
- Engage professional consumer research to seek customer behavioural insights into:
    - Testing manual vs automatic controllability of technologies.
    - Acceptability of new smart technologies, including customer willingness and capacity to change their consumption behaviour.
    - Responses to various signals or incentives by participants.

8.4 PROJECT DELIVERY

The POAS project has successfully rolled out a selection of smart home technologies, including sub meters and smart switches installed on immersion heaters, heaters and electric vehicle (EV) charging stations. This gives owners of EVs the ability to monitor, control and schedule charge times for the first time in Ireland. Other appliances were also installed, including a smart hot water cylinder and a retrofit smart immersion controller. All of these smart devices allow the home owner to turn off, control or monitor power usage of appliances remotely. A second technology involves a smart prepay meter. These customers have elected to have smart prepay meters in their home. They receive an SMS message, requesting a reduction in their consumption manually within the home. Meter data is provided detailing the reduction in electricity consumption following a demand response event.

Smarter Home Technologies - The smarter home allows participants to see exactly how much electricity they're using in real-time and also to remotely control the appliances from their smart phones. Smart switches were also successfully installed on immersions, solar PV generators & diverters and electric vehicles. This is the first time electric vehicle owners in Ireland have had the ability to monitor, control and schedule their EV charge times. This is especially useful if the homeowner has night rate electricity.

FIGURE 4 – SMARTER HOME TECHNOLOGIES

Smart Hot Water Cylinders - A group of participant's trialled smart hot water cylinders. These cylinders are highly insulated and retain heat for a significantly longer period of time than standard cylinders. A proportion of gateways were installed on the cylinders and customers were given an application to operate the cylinder remotely. The gateways allow for remote control for the utility and allow the cylinders to take part in POAS events.

FIGURE 5 – SMART HOT WATER CYLINDERS

Smart Immersion Controllers – Another group of participants tested a retrofit solution to the existing on/off immersion heater switch. This allows them to turn on/off and time the immersion remotely and monitor how much how water they have available.

FIGURE 6 SMART IMMERSION CONRTOLLERS

8.5 DISPERSED LOCATIONS OF POWER OFF & SAVE PARTICIPANTS

The location of participants is spread throughout Ireland. There was no focus on a particular cluster location or specific area of weak electricity network infrastructure.

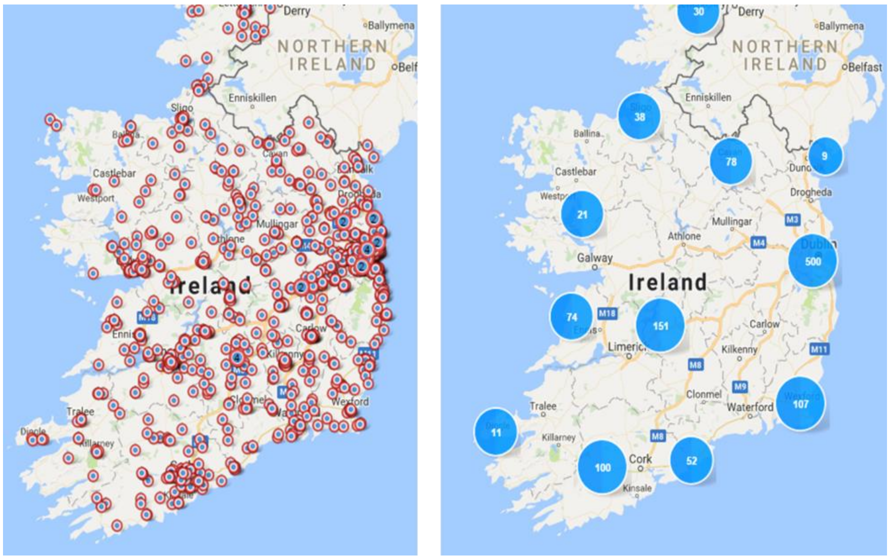

FIGURE 7 - HIGH LEVEL LOCATIONS OF PARTICIPANTS ON THE POWER OFF & SAVE PROGRAMME

8.5.1 KEY LEARNINGS FROM PARTICIPANT RECRUITMENT

- The main reasons for homeowners expressing an interest to participate in the project were as follows (in no particular order):
  - Increasing energy efficiency
  - Helping the environment
  - Academic interest
  - Saving money.
- It was a clear that customers were interested in these smart technologies (energy management technologies); however in many cases to retrofit a hot water tank would involve too much disruption due to size limitations of spacing in the home. For less onerous installations where just control equipment was being installed, this proved successful with high take up
  - Significant work was put in to designing the customer journey for all participants and this proved to be very successful in delivering a very smooth customer recruitment and engagement in the programme – therefore the following learnings are crucial:
  - The homeowner must be at ease and willing to participate in the project in order for the project to run relatively smoothly.
  - During the pilot, updates and tips should be provided to participants in order to keep engaged in the project.
- Participants must be asked for consent up front for their data to be analysed to ensure learnings can be established.

8.6 DATA ANALYSIS METHODOLOGY

In order to ensure the robustness of the analysis, consultants were engaged to design the methodological options for analysing participant response to POAS notifications. Two different approaches were proposed in order to determine a baseline change in consumption over the 30-minute period following the event. These were:

1. Comparison of the Trial Group 30 minute response against a control group that do not receive any notification about the event for this trial.
2. Comparison of the Trial Group 30 minute response against its historical data i.e. consumption for the corresponding 30 minutes period for the previous 5 weeks.

Figure 8 is a depiction of the methodology used to analyse the demand response results. Table 3 below outlines the pros and cons of using either a control group or historical data.

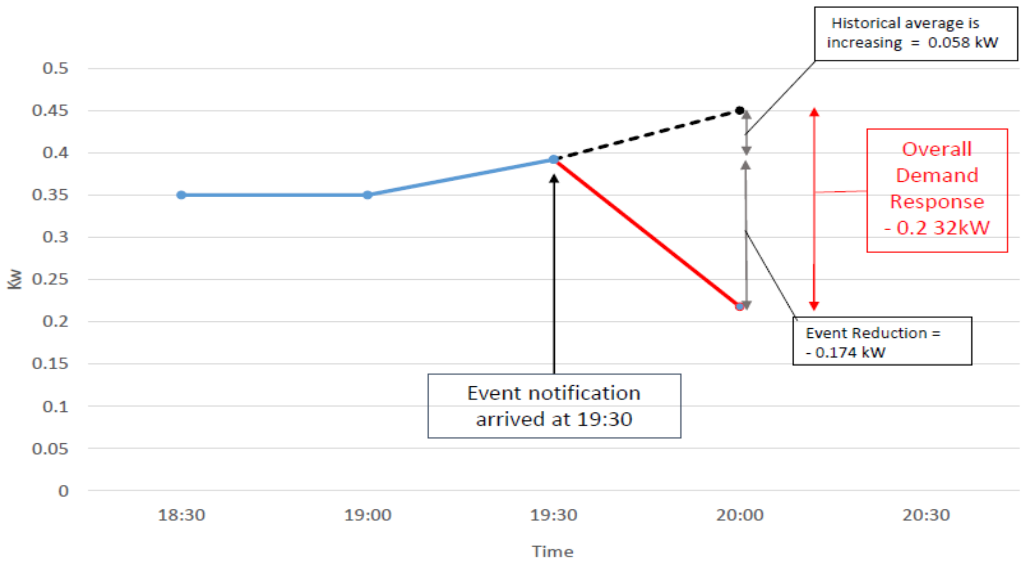

FIGURE 8 - LINE GRAPH EXAMPLE OF AN INDIVIDUAL PARTICIPANT CONSUMPTION AND HOW DEMAND RESPONSE IS MEASURED

TABLE 3 - THE PROS AND CONS OF EACH OF THE APPROACHES DISCUSSED

	Demand response versus a Control Group	Demand response versus Historical Data
Advantages	Standard orthodox approach	Provides a view on the response with respect to the group of participants
	Allows data comparison on the exact same day, time and conditions	Historical data for multiple weeks provides a very stable baseline with better predictive power
	Accounts for black swan events i.e. network blackout	
Disadvantages	Likely to require a larger response to achieve a significant result compared to other methods	Black Swan events make this approach less robust
		Lacks full view of seasonality as limited historical data

For events 1-7 inclusive, the above methodologies for control group and historical data were used. For events 8-10 inclusive, a focus was put on the interruptible load from the automated technologies.

8.6.1 POWER OFF & SAVE EVENTS METHODOLOGY

The methodology designed to run the Power Off and Save Events was a phased approached where;

- Events 1 – 7 inclusive were mainly targeting homes with no automation (i.e. homes that needed direct intervention from the participant to switch off appliances when they get the POAS notification).
- Events 8-10 inclusive were aimed at targeting the more automated technologies that did not need participant intervention.

8.6.2 KEY LEARNINGS FROM DATA ANALYSIS METHODOLOGY

- Both ways of reporting the results were useful in determining the accuracy of the data analysis. It was later determined that both methods had broadly similar outputs in terms of results to the satisfaction of expected event reductions and operation of events.
- Where large numbers of customers are involved – comparison with the control group should provide the more robust result as changing weather, day light conditions, or unusual events (such as popular TV programs) or may cause historical data to be less reflective than a large size control group.

8.7 EVENT PLANNING AND EXECUTION

Notifications were sent out to 1,500 homes to take part in events for 30 minutes where possible once it did not affect the comfort of the home. The events were operated the same way with no advance notification provided to participants prior to events. At the end of the 30 minute period, a second message was sent notifying participants that the event had ended and to switch back on appliances if necessary.

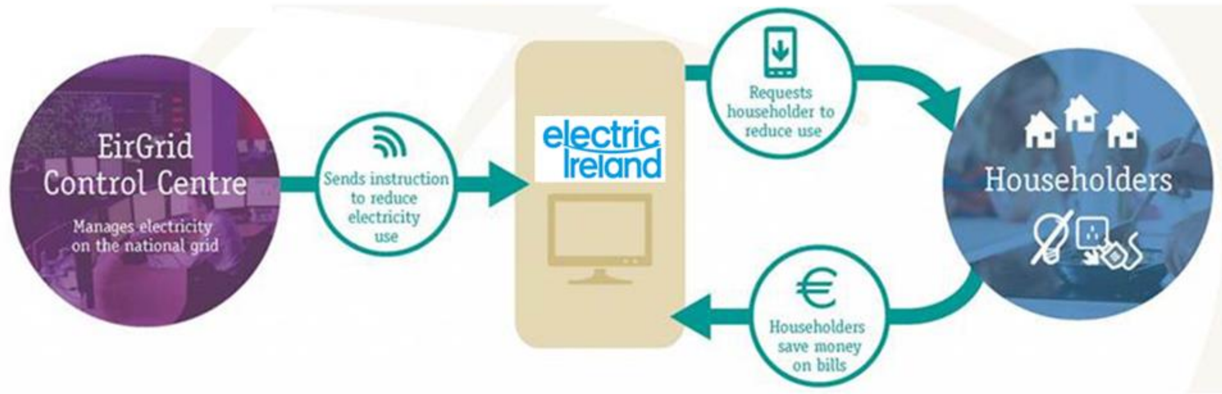

FIGURE 9 POWER OFF AND SAVE EVENT PROCESS – TSO SEND INSTRUCTION TO SERVICE PROVIDER TO ISSUE A DEMAND RESPONSE NOTIFICATION TO HOUSEHOLDERS BY PUSH NOTIFICATION OR TEXT MESSAGE

A third message was sent 24 hours later to survey participants asking them about their participation. POAS events were carried out at various times during the day, week and seasons. For example, event 3 was a weekday at midday and event 5 was on a weekend in the evening. For the automated technology events, the project team strategically targeted the best times for available load reductions. For example;

- Smart hot water immersion loads – Targeted in the morning between 05:00 – 07:00 hours and evening 16:00 – 20:00 hours.
- Glen Dimplex's Quantum hot water smart cylinder loads – Targeted at 00:15 hours only
- Electric Vehicles – Targeted generally in the evenings. Early mornings were possible also.

Night time POAS events were only possible for the automated technologies as participants did not receive a SMS notification for their interruption as this would have impacted on the comfort level of customers.

8.7.1 PARTICIPANT RESPONSE LEARNINGS

- Responses from participants generally aligned with daily demand curves during the week. There were good overall reductions during the morning and evening peaks however; there were lower overall reductions during the day and at weekends.
- Participants react quickly (in the order of minutes) to a text message notification. This can be seen from the data analysis captured on the Smarter Home participants, for whom we collected 5 minute data.
- At least a third of customers reduce their consumption within the first five minutes of a notification being sent.
- The peak reduction times occurred at approximately 20 minutes and 25 minutes respectively.
- Accounting for the relevant participants over 50% of participants reduced their consumption for the 30 minutes of the event when compared to the half hour before each event.
- Although customers are signed up and may have taken part in the event, there are some cases where there are communication issues in terms of collecting the data.
- For the automated technologies there were very fast interruptions once the event was triggered. One second data was observed on homes with the Smarter Home technology and it could be seen that generally 20% of homes reduced within 90 seconds for both events 6 and 7 respectively. Depending on the signal strength of technology in the home, either broadband or GSM, the interruption could be observed in the order of 1-10 seconds.
- Events 8-10 which focused on automated events for larger loads turning off hot water for 15 minutes and/or car chargers for 30 minutes were successfully carried out without causing discomfort or requiring the response of the customers. The finding here is that this is the optimum way of maximising the response. However diversity of load will reduce the available load at any time.

8.7.2 DSM TECHNOLOGY LEARNINGS

From working on the design, development, implementation, mobilisation and operation of the various technologies, there were a number of learnings gathered.

- The use of a range of smarter technologies required on homes using the technology needed to have fix line broadband. Careful selection of participants was needed where a filter on having broadband being an important requirement.

  Smart cylinders required a longer customer journey. This was due to the extra elements, initial online survey, customer home visits. This had to done before the installation of a new hot water smart cylinder. A final visit to the home was required when the gateways were ready to be installed.

8.8 FORECASTING POTENTIAL DEMAND RESPONSE IN 2030

To consider the potential for demand response when these technologies are adopted, the information from our data sets combined with a scenario for customer take up of these appliances, is scaled up to consider what can potentially be achieved. It is worth noting that, electric vehicle charging, heat pumps and immersion load are the significant loads in the home. With the development of more smart technology being introduced, their potential may increase in the coming years. The summary of response based on the EirGrid's Customer Action scenario[4] outlined in Tomorrows Energy Scenarios.

TABLE 5 – FORECASTED DEMAND RESPONSE POTENTIAL FROM TECHNOLOGIES

2030 Scenario	Morning Demand Response (MW)	Evening Demand Response (MW)
Electric Vehicles 560,000 EVs	60	146
Heat Pumps 339,000 homes with heat pumps	170	170
Manual load(200,000 homes)	16	23
Homes with electrically heated water and opted in Immersion control 300,000	98	50
Total	344	389

It should be noted the load profile of energy use might change from this into the future, based on customer's behaviour or based on smart charging services that will shape the load to leverage low electricity costs, increased renewables or provide flexibility services.

8.8.1 ELECTRIC VEHICLES IN 2030

Taking the snapshot of the charge profile of the 10 EVs participating in POAS and assumed system peak times of 06:00 to 09:00 and 16:00 to 20:00 the interruptible peaks for EVs was determined. In POAS, the EV load that was available to be interrupted was 11.5% of the total EV load installed. Factoring this up to EirGrid's 2030 scenario of 560,000 EVs, a potential 225.4 MW could be available for flexible services at system peaks, with more or less than this available at other times of the day.

However, based on the small number of EV profiles that was gathered during POAS and, the average during the two peak times were 60kW in the morning and 146 MW in the evening. On the other hand, the available service volume throughout the night would be in excess of this as can be seen from Figure 9.

[4] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Tomorrows-Energy-Scenarios-Report-2017.pdf

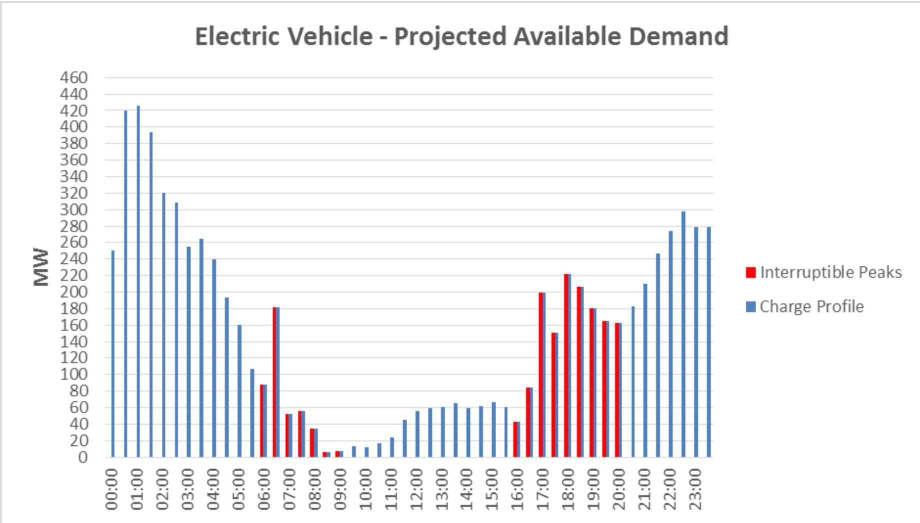

FIGURE 10 – PROJECTED AVAILABLE DEMAND REDUCTION FROM ELECTRIC VEHICLE

8.8.2 HEAT PUMPS IN 2030

EirGrid's Consumer Action scenario predicts up to 339,000 homes will have heat pumps installed in 2030. Each heat pump has a potential 1.5kW – 2.5kW load, resulting in an approximate maximum load of 850 MW. With diversification, the peak loads can potentially be reduced by up to 20%. Thus, providing up to 170 MW for network flexibility.

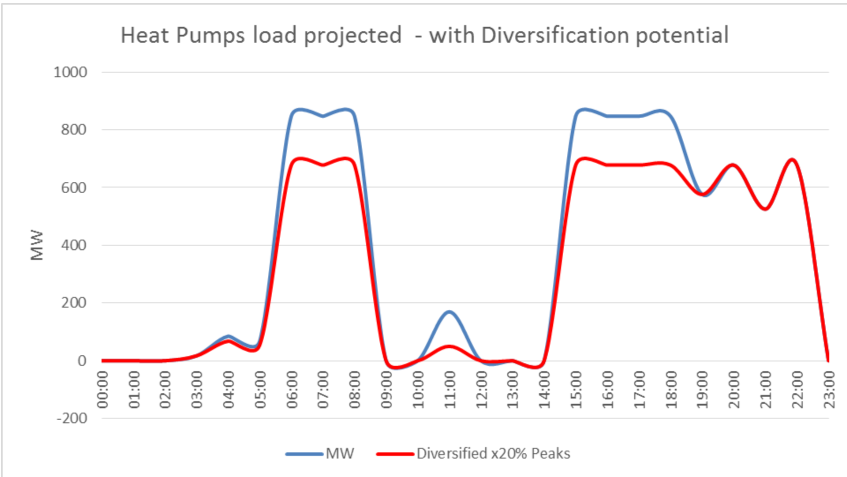

FIGURE 11 - PROJECTED AVAILABLE DEMAND REDUCTION FROM HEAT PUMPS

8.8.3 RESIDENTIAL DEMAND

In POAS a 17% demand reduction for the evening peak and a 15% reduction for the morning peak were observed. With 200,000 customers taking part in a national scheme there is potential to reduce the peaks by 23 MWh (evening) and 16 MWh (morning). Based on daily consumption data collected from 662 customers, the daily profile for 200,000 customers is presented in Figure 12 below.

FIGURE 12 - PROJECTED AVAILABLE DEMAND REDUCTION FROM RESIDENTAL DEMAND

8.8.4 IMMERSION HEATERS

During the course of POAS 17% of immersion heaters were actively heating water and available to be reduced during a single event. However, to get a wider view of the predicted load we analysed January 2018 data for 45 Climote users who were using their immersion heater with a load of more than 1 kWh per day. On average, the load to be switched during assumed system peak times of 06:00 to 09:00 and 16:00 to 20:00 would be 327 MW and 167 MW respectively. As seen from the load profile in Figure 13 the demand for hot water occurs between 4AM and 8AM. By 2030, if 300,000 of homes have an active immersion heater opted in for demand response; this could result in a potential demand reduction of approximately 98 MW at peak times. This is quite close to what would have been estimated by using 17% proxy determined from POAS (102 MW).

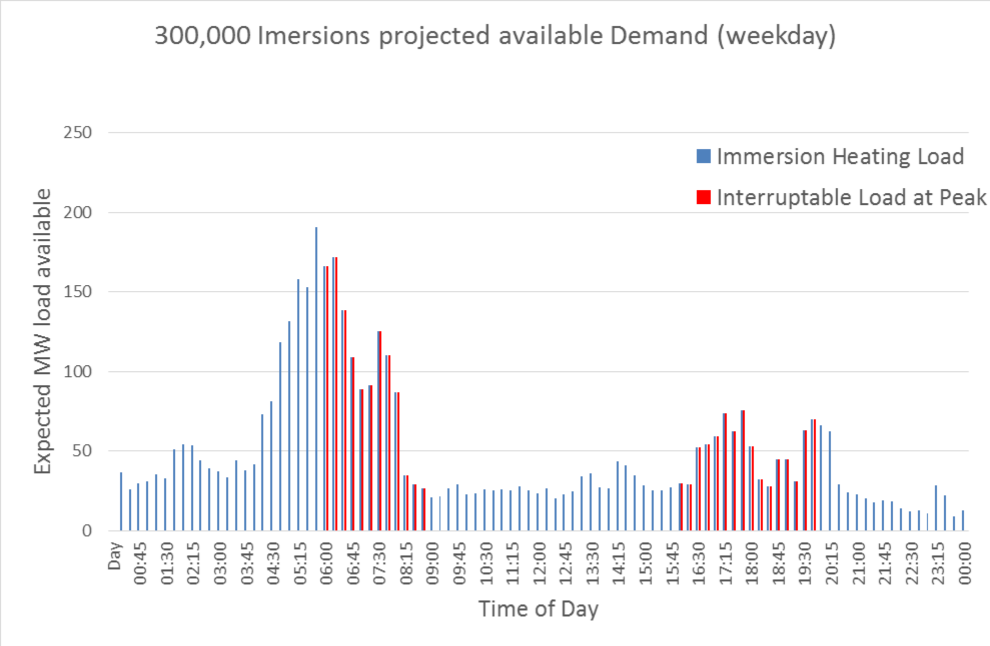

FIGURE 13 - PROJECTED AVAILABLE DEMAND REDUCTION FROM IMMERSION HEATERS

8.9 POWER OFF & SAVE LEARNING & OUTCOMES

Considering all of the above insights and learnings from the Power Off and Save Project, the following are suggested recommendations to operate a much larger trial with the view of participation within an enduring services marker:

- Careful planning and delivery of customer engagement from recruitment to participation is the single most important aspect of delivering a successful residential demand response trial,
- Customers embrace new smart technology; however technology that requires significant work in the home such as retrofitting a cylinder should be avoided in preference of using existing technology with smart controls,
- Secure & reliable communications with smart technology is required at all times. Ideally with a backup communications option e.g. broadband or GSM,
- Data availability, accuracy, reliability and speed of collection are a critical requirement for performance monitoring,
- The monitoring equipment within the home or of a technology is recommended to have 1 second data and frequency measurement capability,
- It is critical to involve both TSO and DSO, as smart home technologies can have an impact on the distribution network. Greater coordination between TSO and DSO network operators will allow for increased visibility and potential in flexible services,
- A cluster approach to residential service providers could potentially provide greater flexibility to the network operators relax network limitations, and
- It is recommended that technologies should the capability to accurately forecast its potential service volume of service provision

9. NODAL CONTROLLER TRIAL

9.1 NODAL CONTROLLER OVERVIEW

The Nodal Controller (NC) is a means by which distribution connected generation can provide reactive power support to the TSO. Whilst at the same time, ensuring that all relevant distribution parameters are kept within secure limits. Thus, avoiding damage to or limitation of other users of the distribution network. In essence, it takes set-points from the TSO and distributes them to participating wind farm power stations (WFPS). If any local current or voltage violations are encountered or anticipated, the NC can deliver as much support to the TSO as the prevailing conditions and the commercial choices and contractual commitments of participating WFPS will allow.

9.2 REACTIVE POWER NEED

In Ireland and Northern Ireland, the need for Steady State Reactive Power (SSRP) from new sources has been identified due to the following reasons:

- Increased loading and distance (low voltage)
- Distribution connected generation set-up absorbing reactive power (low voltage)
- Displacement of conventional generation (voltage control)
- More underground cable connections (high voltage)
- Increase in harmonic filters (high voltage)

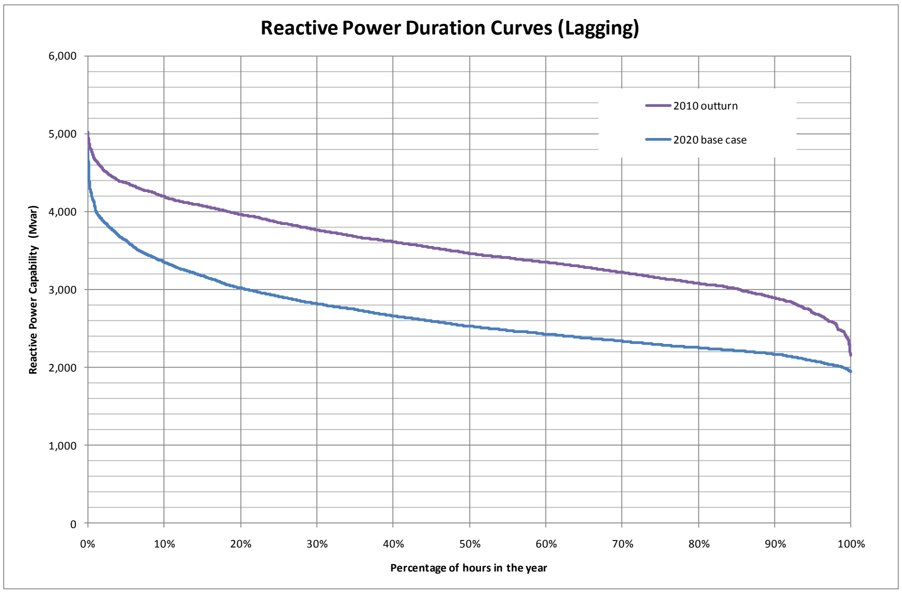

FIGURE 14 – REACTIVE POWER DURATION CURVES IN IRELAND AND NORTHERN IRELAND 2010 VS. 2020

In Ireland and Northern Ireland wind farm power stations (WFPS) connected to the distribution system have traditionally been set up absorbing reactive power. This is to maximise active power output, which, the distribution system can accommodate without local over voltage issues.

However, as a result of meeting this reactive power demand, low voltage issues occurred on the transmission system. In addressing this issue, the DSOs in Ireland and Northern Ireland initiated separate trials. The trials were chosen to take place at dedicated WFPS cluster nodes i.e. no customer load connected. The location was chosen based on the need to implement a low voltage control solution in the area. Following a number of detailed studies on a windfarm cluster which contained 168 MW of distribution connected wind at a 110 kV transmission node. The aim of the study was to assess the needs of the system in the area with regards to voltage control and to identify violations of standards and propose solutions.

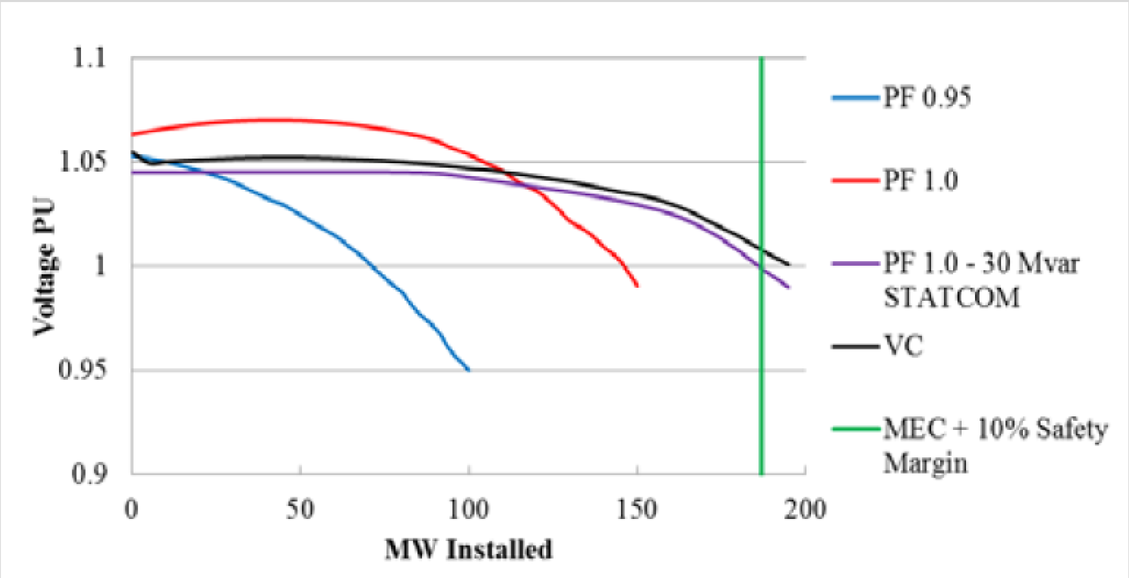

FIGURE 15 - VOLTAGE PLOTTED AGAINST MW CONNECTED AT A 110 KV TRANSMISSION NODE

The study indicated a risk of voltage collapse as the wind capacity increased in the area due to the DSO practice of operating the wind farm power stations (WFPS) with an absorbing power factor. As a result of the outcomes of this analysis, the DSO in Ireland changed the operational settings of all cluster WFPS to unity power factor. In Northern Ireland, all WFPS were to be operated using a smart power factor. The details of both DSO projects are discussed on Sections 9.2.1 and 9.2.2 of this report. The results also concluded that, by operating in voltage control mode (as opposed to a fixed power factor), the total planned amount of wind could be facilitated on the system, without a need for additional voltage support.

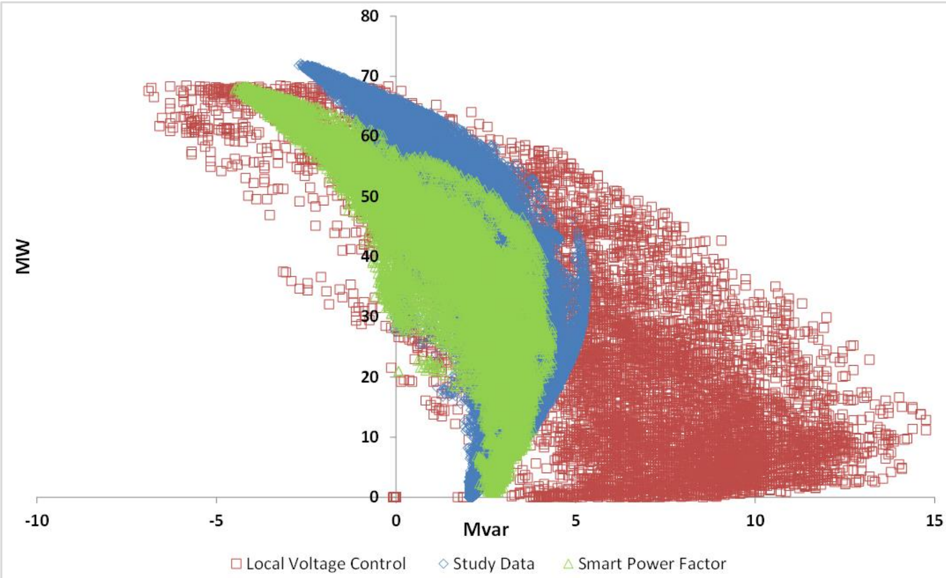

FIGURE 16 – IMPACT OF SMART POWER FACTOR ON REACTIVE POWER AT 110KV TRANSMISSION NODE

9.2.1 NODAL CONTROLLER IN IRELAND

The NC pilot project will be commissioned and tested in Q4 2018. It will initially involve only the one WFPS, with up to six WFPS totalling 168 MW being brought on to the NC via three 110/38 kV transformers. These will take place 2019, as works at the WFPS are completed, and they pass their individual testing phases. The NC will continually transmit an estimated MVar range at the TSO-DSO interface to the TSO control centre. The TSO will choose a mode of operation, from the four modes available and issue a set point.

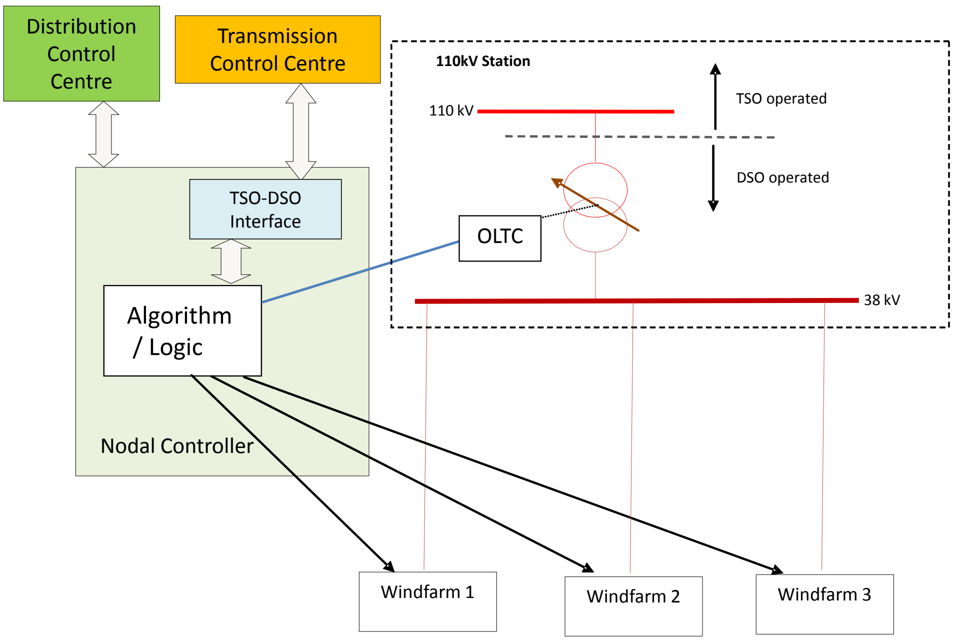

FIGURE 17 – HIGH LEVEL NODAL CONTROLLER DESIGN IN IRELAND

There are four control modes within the Ireland NC, they are:

1. Nodal controller in reactive power dispatch mode and the WFPS in reactive power dispatch mode

2. Nodal controller in reactive power dispatch mode and the WFPS in voltage control mode
3. Nodal controller in voltage control mode and WFPS in reactive power dispatch modes
4. Nodal controller in voltage control mode and the WFPS in voltage control mode

If the nodal controller trial is successful and is rolled out across all cluster stations in Ireland, it could provide access to >250 MVar to the TSO.

9.2.2 NODAL CONTROLLER IN NORTHERN IRELAND

The NC pilot project will be commissioned and tested in Q1/Q2 2019. It will be located at a dedicated WFPS cluster station that has 136.6 MW of WFPS connected. The NC will be tested over a one year period to ensure all operational complexities are well understood for a wide variety of system operation scenarios.

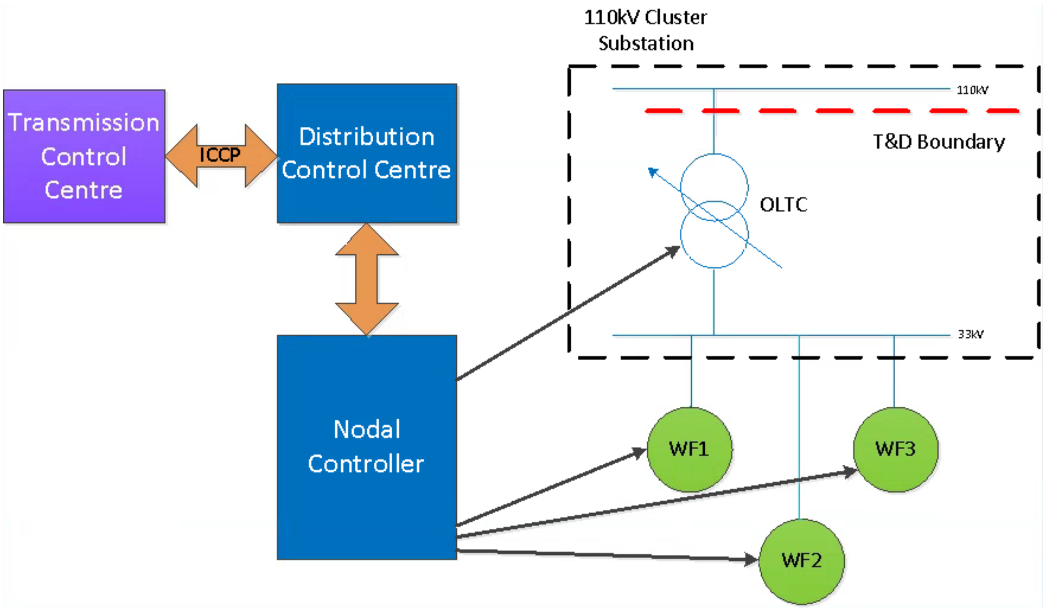

FIGURE 18 – HIGH LEVEL NODAL CONTROLLER DESIGN IN NORTHERN IRELAND

There are three control modes within the Northern Ireland NC:

1. Power Factor control mode (operating at a fixed power factor)
2. Reactive Power control mode (dispatching of MVar)
3. Voltage control mode (changing MVar output to maintain a voltage set point)

The NC will aim to:

- Ensure stable operation of the WFPS i.e. no hunting
- Protect the transmission and distribution system from voltage and thermal violations
- Ensure efficient use of the system i.e. optimised use of the on-load tap changing transformer

If the nodal controller trial is successful and is rolled out across all cluster stations in Northern Ireland, it could provide access to >250 MVar to the TSO.

10. CONTROLS AND SIGNALS PROJECT

10.1 CONTROL AND SIGNALS PROJECT OBJECTIVE

Due to the increasing use of renewable energy sources, TSOs worldwide are seeing a shift from operating a centralized portfolio of large conventional fossil-fuel generators to a more widely distributed network which includes small-scale generation. As a result, the cost implication to enable two-way communication between the generator and the network operator are increasing, when compared to a conventional generator, particularly where multiple small sources are providing the service. As a result, there is a need for network operators to ensure they are supporting the changes in industry. By implementing new communication protocols and standards the cost to enter the service market can potentially be reduced. This has the potential to remove barriers for new technology to participate in an enduring service market.

In Ireland and Northern Ireland small scale generation may increase from 1,159 MW in 2018 to 1,402 MW in 2020, the Control and Signals trial will look to address and identify the barriers to market participation and increase System Operator visibility. The findings and implementation of new protocols are expected to remove barriers and enable new technologies to connect to the grid. If protocols are not revised for small scale projects, the current cost and complexity for telecommunication will remain in place.

10.2 PROJECT SCOPE

The scope of this project includes an assessment of the current telecommunication protocols, which will be tested through reviewing the current technologies and completing a trial with industry participants to help identify the challenges of utilising a new telecommunications protocol. The final deliverable will be to propose a protocol, which is fit-for-purpose, scalable and meets the shifting needs of the industry. This project is expected to be completed in Q1 2020. At present, all service providers use a standard Remote Terminal Unit RTU device and IEC101 communications protocol.

The trial will be delivered in three phases over the duration of 2018/2019:

- **Phase 1** - Investigation of current protocols available and assessment of the measurement requirements. This investigation will include an assessment of the current requirement and a preliminary report will be prepared, outlining potential alternatives communication protocols to be trialled in Phase 2.
- **Phase 2** - A system trial of the proposed protocols is to be performed with market participants through the QtP. The trial will examine the visibility and reliability compared to the current standards. Based on the results of the trial, a new communications requirements and standards will be proposed. A learning and outcomes report will be prepared in Q4 of 2019 recommending the next steps for the trialled protocols.
- **Phase 3** - This phase is to implement the findings of Phase 1 and 2. This phase includes the roll out of the new protocol to industry including the communication and implementation of the new standards.

10.3 KEY DELIVERABLES

The following deliverables are to be considered over the timeline of the project:

- Complete assessment of industry protocols that is currently available.
- Internal system implementation and test environment set up (new signals from selected protocol to be received and tested).
- Complete trial assessment and testing through industry engagement.
- Report recommending implementation of protocols.
- Implementation of protocols and industry roll out of changes.

10.4 ASSOCIATED OPERATIONAL COMPLEXITIES

- The selected protocols may not be fit for purpose as the trial may highlight unforeseen issues.
- The trial may be limited in the technology types selected which may result in the implementation of these protocols with technologies that may not be suitable.
- Scalability of protocols will be monitored as it may be difficult to fully assess the impact of protocols from an operational complexity perspective.

10.5 EXPECTED LEARNING OUTCOMES

- Understanding of the protocols available and the complexity and cost of implementing protocols for both the TSO and market participants.
- Understanding the practical implementation of these protocols from both a market participant perspective and TSO perspective.

11. SUMMARY AND 2019 TRIALS

The 2018 Qualification Trial Process focused on building on the learnings and outcomes of 2017. Following the completion of the Qualification Trials for 2017, the TSOs have identified twenty six findings outlined in Appendix A of this report. As a result, the TSOs expanded the scope of the QtP across the EirGrid Group to incorporate a wider range of topics and considerations. 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.

For the 2018 Qualification Trial Process, three projects were selected to examine barriers to large scale deployment. The trials focus on three technical considerations network limitations, communication and future barriers for embedded service providers. Building on the 2017 and 2018 trials, two focused workstreams have been identified for further development in 2019. A QtP technology integration forum will be established and new set of qualification trials will take place in 2019.

11.1 2019 QTP TECHNOLOGY INTEGRATION FORUM

2019 QtP - Technology integration forum, the technology forum aims to provide a forum to discuss and address issues which associated with the large scale deployment of new technology in the transmission system and its capability to provide system services. The forum consists of industry participants from across Ireland & Northern Ireland. This may potentially include representatives from academia and industry across Ireland, Northern Ireland and Europe. Separate technology forums are to be held approximately every four months. A range of technologies will be discussed at the forum. The output of the forum is twofold. Firstly, to inform the scope development of the QtP and secondly inform solution development implementation within the TSO. . As the forum develops over more technology categories will be investigated.

11.2 2019 QUALIFICATION TRIAL PROCESS

The 2019 Qualification Trial Process will include Provenability, Distribution Impact and Standard & Compliance trials to demonstrate capability in the reserve, ramping and fast-acting services. SIR and SSRP are inherent capabilities of technologies. The trial s will be designed to be bespoke with a focus on innovative technologies and strategy. A detailed overview of the trial categories are outlined below;

11.2.1 PROVENABILITY TRIALS

Provenability Trials – Any technology class not currently "Proven" as per a public list published on the TSOs website[5]. Two categories selected for the Provenability Trials are, Solar and Other Technologies. The trial participants will be required to be capable of meeting requirements set out in the DS3 Performance

[5] http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-System-Services-Proven-Technology-Types.pdf

Measurement Device Standards for Fast Acting Services[6]. The technologies captured in the 'other technologies' class include, but are not limited to:

- Energy Storage Units including Battery storage/ Compressed Air Energy Storage (CAES)
- Flywheels/ Rotating Stabilisers
- Hybrid applications consisting of combinations of the above technologies including hybrid applications with wind generation.

Other technologies will be examined on a case-by-case basis where they are not currently listed under the Proven Technology list. This category also allows for potential service providers to propose a project with the aim of meeting the objectives of the service product definitions. The maximum size of service provision that a Providing Unit must be capable of providing cannot be less than 1 MW for Solar – this is in line with the minimum Providing Unit size requirements in the enduring services market.

For 'Other Technologies', the equivalent minimum threshold of Service capability on a Providing Unit basis cannot be less than 100 kW. This will facilitate participation by a range of smaller-scale technologies. The maximum service provision per Providing Unit from a contractual perspective is 5MW. During the Provenability Trial, the TSO will monitor the provision of the services in response to real events on the power systems of Ireland and Northern Ireland.

Should there be no suitable events on the system over the entire duration of the trial, the TSOs may utilise smaller frequency disturbances on the system to assess Service provision. In addition, the TSO may also use scheduled system events and dispatches to determine responses from service providers. Scheduled system events are rare and will not be specifically driven by the Qualification Trial Process.

11.2.2 DISTRIBUTION IMPACTS TRIALS

Distribution Impacts Trials – Focused on distribution technologies who have not qualified due to issues on the distribution network such as congestion management, protection issues or violation of operation protocol. This allows for small-scale technologies to be trialled as system services providers in a controlled transparent manner. The bulk of these new technologies will be connected to the distribution system in Ireland and Northern Ireland.

11.2.3 STANDARDS AND COMPLIANCE TRIALS

Standards and Compliance Trials (Measurability) – Standards and Compliance Trials will replace the previous Measurability Trials. Under the current arrangements the TSO has developed DS3 Performance Measurement Device Standards for Fast Acting Services[6].

[6] http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-Performance-Measurement-Device-Standards-for-Fast-Acting-Services.pdf

These trials will be open to trialists whose technology classes are proven but wish to demonstrate novel approaches to current compliance and standards. This could possibly be broken down into two sub-categories; visibility and controllability consisting of any of the following;
New approaches to measurement of aggregators;

- Small Scale Aggregation,
- New mechanisms for provision of signals,
- Technologies providing services in an inherently different approach.

Participation in the Standards and Compliance Trials will require service providers to provide a mechanism to measure the delivery of the services in response to real events on the power system of Ireland and Northern Ireland. Should there be no suitable events on the system over the entire duration of the trial, the TSOs may utilise smaller frequency disturbances or voltage deviations on the system to assess service provision.

APPENDIX A

12. 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.

QUALIFICATION TRIALS PROCESS

OUTCOMES AND LEARNINGS 2017

EIRGRID 30.04.2018

EU-SysFlex

Contents

Executive Summary

As part of the Delivering a Secure Sustainable Electricity Programme (DS3), the Qualification Trials Process (QTP) commenced in March 2017. The trials consisted of fifteen individual technology trials across twelve separate Providing Units. The breakdown of trial technologies is shown in Table 1 below. Eight trial categories were assessed in total.

Provenability			**Measurability**		
DS3 System Service	Technology Category	Participants	DS3 System Service	Technology Category	Participants
POR	Wind	2	FFR	CDGU	1
POR	Wind (with Emulated Inertia)	3	FFR	Wind	1
POR	DSM	2	FFR	DSM	1
POR	Sync Comp (Energy Storage Unit)	1	FFR	HVDC Interconnector	2
			FPFAPR/DRR	CDGU	1
			FPFAPR/DRR	Wind	1

Table 1: List of 2016/17 DS3 Qualification Trial Categories

<u>The trials ran for 6 months with two core objectives:</u>

1. To identify if the trialists' technologies could provide a response to an event in line with the DS3 System Services definition of the Service they were trialing; and
2. To identify any operational complexities driven by the provision of 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, trialists were required to demonstrate responses to real system events that occurred during the trial period, in line with the DS3 System Services definitions.

Objective 2 required more careful consideration of how each technology provided the Service being trialled and what impacts they had on current TSO processes and systems. The outputs of objective 2 will inform the development of the TSOs' standards and processes to manage System Services from different technologies.

These outputs will also inform the development and enhancement of the TSOs' systems for performance monitoring, scheduling and settlement of Services, as well as external processes and outputs such as product design decisions, procurement considerations / eligibility, and compliance and standards described in the DS3 System Services Protocol document.

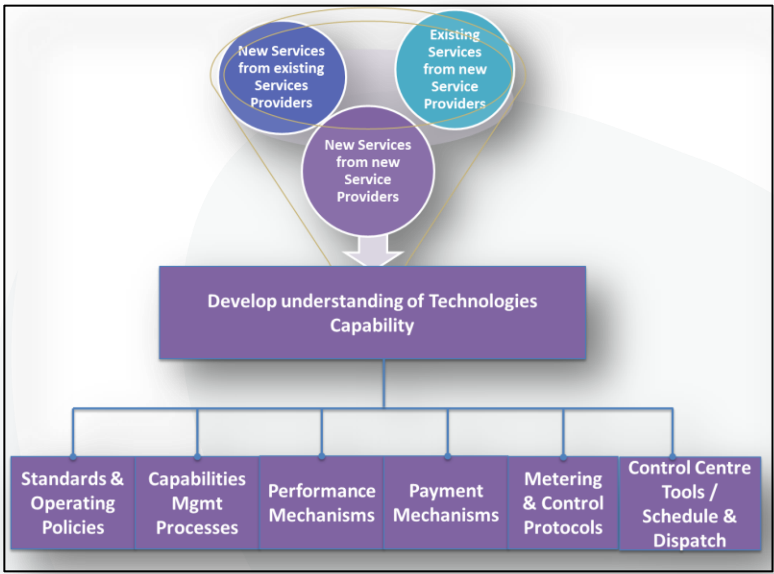

Figure 1: Graphical Representation of DS3 Qualification Trial Objectives

It is a finding of the 2017 QTP that all technologies participating in the POR and FFR trials should be considered as proven technologies for these Services going forward.

It is a finding of the 2017 QTP that all technologies participating in the DRR and FPFAPR trials should not yet be considered as proven for the provision of these Services. However, the TSOs propose that alternative approaches will be undertaken to further understand the provision of DRR and FPFAPR in order to determine how various technologies can be deemed proven for these Services in advance of the Central Procurement Process. This will likely be based on the evaluation of historical fault record data gathered by the TSOs.

Table two provides an overview of the technologies that should be considered to be proven for particular System Services arising from the 2017 QTP. Classification as a proven technology arising from the QTP will inform the TSOs' management of the procurement process for the provision of System Services for Regulated Arrangements. It does not guarantee that a Service Provider will receive a contract – this will be determined based on the tendering party's technical submission. The full list of technologies proven to provide System Services by EirGrid and SONI can be found here. As part of the procurement process, the tendering party's ability to adhere to minimum standards relating to testing, compliance and signals installed, which have been identified by this trial process, may be evaluated. Therefore, although a technology class may be considered proven for the provision of a particular Service, there may be specific work to be undertaken by individual tenderers in order to be successful in any procurement process.

Technology Class / Sub Class	Services Applicable
Wind - Wind Farm Control	FFR, POR, SOR,TOR1
Wind – Emulated Inertia	FFR,POR
Demand Side Management (DSM)	FFR,POR,SOR,TOR1
Hybrid of a Synchronous Compensator and Flywheel	FFR, POR,SOR,TOR1
Centrally Dispatched Generating Unit (CDGU)	FFR
HVDC Interconnectors	FFR

Table 2: Technologies that may be deemed Proven Technologies for future procurements

Following the completion of the Qualification Trials for 2017, the TSOs have identified twenty six findings. These findings will inform the TSOs' decisions relating to System Services product design, procurement and contractual arrangements, and other TSO systems and processes. The rationale for each of these findings can be found throughout this report.

Managing the Transition to New Technologies

Over the past ten years we have seen increasing changes in the technology that makes up our electric power system. Today, and in the future, 'behind the meter' technologies such as rooftop solar PV, Battery Storage, Vehicle to Grid Charging and energy management systems are changing the power system. The need for greater transparency of data and information will also drive change across the sector. As renewable generation (wind & solar), displaces conventional generation on the system, we need System Services to come from sources other than conventional generation.

A transition to a power system with high levels of non-synchronous generation will result in new system scarcities. These scarcities are caused by increased need for volumes of certain Services firstly and, secondly 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 to get System Services from an enhanced portfolio of Service Providers, consisting of a mixture of the existing Service Providers, 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 reliance on these technologies. This confidence is developed through operational practice, learnings and continual improvement. The TSOs 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 Service Providers needs to be managed in a prudent manner, allowing the TSOs time to study and assess the impacts of new technologies in a controlled manner. This helps to ensure that outcome of an enhanced portfolio of Service Providers, whilst also ensuring the system is managed in a secure, reliable and efficient manner.

The DS3 Qualification Trials Process

The DS3 Qualification Trials are the mechanism through which the TSOs are managing this transition to a wider portfolio of System Services' Providers. The trials aim to identify operational complexities caused by new technologies or Services, develop understanding of these and suggest solutions on how to integrate these technologies into the TSOs' processes and systems. The first trial period started in March 2017. Specifics of the trial's format for 2017 are described in more detail in the next section. The trials are envisioned to run on an annual basis, with the qualification process, timelines and format of future trials currently under development for 2018.

Trial Principles

There are a number of key principles which underpin the DS3 Qualification Trials;

1. The trials are run at small scale allowing trialists 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 TSOs consider a technology's ability to provide a number of System Services within a Service category as proven. An example of this is that a successful participation in a POR trial may be considered as proof of the capability to also provide SOR and TOR1.

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 OEM. 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 a specific trialist in the Qualification Trial does not necessarily exclude its technology class from provision of the Service forever. Depending on the reasoning for the failure of a trial, the TSOs 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 Qualification Trial process 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.

2016 - 2017 DS3 Qualification Trials Process

The Qualification Trial process format for the tariff year of 2016 - 2017 was decided through an industry consultation. The trials began operationally on 1 March 2017, lasting for six months. The trialists were selected through an open procurement process run from November 2016 to February 2017. High level trial dates and key milestones for the 2016-2017 trials are shown in Figure 2 below.

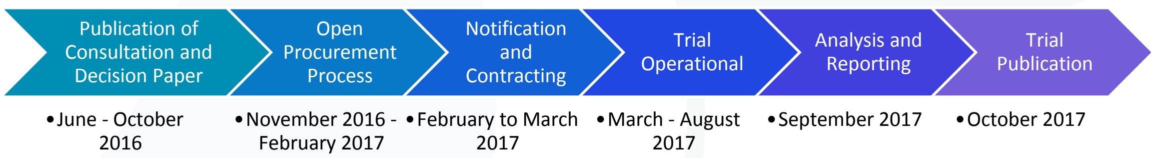

Figure 2: Key Milestones for the 2016-17 DS3 Qualification Trials

Trialled Product Descriptions

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.

Fast Post-Fault Active Power Recovery

The Fast Post-Fault Active Power Recovery (FPFAPR) Service provides a positive contribution to system security. Fast Post-Fault Active Power Recovery is defined as having been provided when, for any fault disturbance that is cleared within 900ms, a plant that is exporting active power to the system recovers its active power to at least 90% of its pre-fault value within 250ms of the voltage recovering to at least 90% of its pre-fault value. The Service Provider must remain connected to the system for at least 15 minutes following the fault. The FPFAPR volume in a settlement period is based on MW output during that period.

Dynamic Reactive Response

Dynamic Reactive Response (DRR) Service is defined as the ability of a unit when connected to deliver a reactive current response for voltage dips in excess of 30% that would achieve at least a reactive power in MVAR of 31% of the registered capacity at nominal voltage. The reactive current response must be supplied with a Rise Time no greater than 40ms and a Settling Time no greater than 300ms. The volume is based on the unit's registered capacity when connected and capable of providing the required response. The measurement of this product requires that high quality phasor measurement units be installed at the provider's site with appropriate communication and access arrangements agreed with the TSOs.

Provenability

This section focuses on attempting to "prove" each of the technology classes participating in the DS3 System Services Qualification Trials. Each trial is considered as part of one of eight trial categories. Each trial category is assessed under the following sub headings;

- Background,
- Operational Complexities and Findings.

Provision of Service focused on how each trial participant responded to system events when called up during the trials.

Operational complexities were identified across a number of current TSO working assumptions, processes, tools and standards. The report findings consider how these operational complexities can be managed. These findings will inform the development of the following:

- TSOs' contractual arrangements and procurement processes,
- TSOs' internal processes for the management and scheduling of Services, and
- TSOs' systems used to control, monitor performance, and remunerate Service Providers.

EU-SysFlex

CDGU - FFR Trials

Background

The main purpose of this trial category was to better understand whether CDGUs can effectively provide Fast Frequency Response FFR within a shorter horizon window required of FFR between 2 – 10 seconds (or quicker). Two units qualified under this trial category to respond. Both units were set up to provide a dynamic response. Provision of the FFR Service for each event was considered under two areas of focus:

1. **The trialist's initial response** - taken as a snapshot of the unit's megawatt (MW) increase achieved at the start of the event horizon (i.e. at the two second mark). The initial time of two seconds was calculated based on the time after the first point the system frequency dropped below 49.8 Hz, which is in line with the TSOs' current approach to performance monitoring.

2. **The trialist's average response** - taken as the average MW increase versus expected provision over the entire two to ten second horizon.

Operational Complexities

As CDGUs currently provide POR, there are not many operational complexities which need to be considered for the provision of FFR. The key issues and learnings identified through the QtP primarily related to performance monitoring. These are described below. Inertial swings lead to interactions between the unit's inertial response and governor control response, meaning the megawatt output of the machines close to the start of the response times can become oscillatory, difficult to measure and difficult to distinguish between inertial response and governor control.

Identification and contracting of sub two second responses

Compliance testing of CDGUs shows that in general there is a lag between the injection step and the beginning of the response of the unit to the step. This time delay can be in the region of one to two seconds in some cases. Additionally, once the unit begins to respond, its active power output will be limited by the speed at which the unit can respond; this tends to be significant in the case of CDGUs, taking minutes to achieve their maximum output from a minimum output position.

The TSOs consider that it may be appropriate to implement the following approach to determine the sub-2 second response times for provision of FFR:

1. A Service Provider's contracted volume remains based on the minimum volume provided over the 2 to 10 second horizon window of FFR during a compliance test.

2. Where a unit can provide a response prior to 2 seconds within 90% of the maximum volume recorded over the FFR window (2 to 10 seconds) during this test, then this unit is eligible for the Product Scalar for the Faster Delivery of FFR.

3. The exact speed of response of the two-second-response time is taken as the last sample with number 2 above.

4. The test must be undertaken with data granularity of 20 milliseconds (ms) or less in order to be considered as satisfactory proof for provision of the Product Scalar for the Faster Delivery of FFR

Finding 1 - Application of the Product Scalar for the Faster Delivery of FFR

Consideration should be given to only applying the Product Scalar for the Faster Delivery of FFR to units that can provide 90% of their maximum recorded provision identified during the testing process over the FFR timeframe.

The overall volume contracted for FFR in such cases would remain based over the minimum provision identified during testing over the FFR window (2 to 10 seconds).

In respect to aggregators of Services, the same principle would apply based on the aggregate response of the DSU as a whole achieving within 90%.

Performance Monitoring of FFR Responses

Learning's from trial data showed that CDGUs in general had issues in relation to their response times and the impacts of inertial swings could be significant in terms of their overall response provided during an event. However, the units will initially appear to respond in swings greater than their expected responses due to these inertial swings. These learnings have a number of implications for performance monitoring of FFR:

1. The use of a snapshot approach at 2 seconds, similar to what is applied under POR, is likely to lead to significant changes in a unit's response recorded to events due to -the oscillatory characteristics of their response during these time periods;

2. Distinguishing performance of a CDGU in the sub two second time window is difficult to achieve as the effects of inertia are most prevalent in this time window;

3. The learning's of the trail indicate that CDGUs find it most difficult to achieve response in the early stages of the FFR horizon.

Finding 2 - Performance assessment of FFR by CDGUs to cover the entire FFR window but weight the initial response more heavily

The use of a snapshot in the performance monitoring of the provision of FFR by CDGUs may not be a reliable metric. Consideration should be given to applying a time-weighted averaging of data samples over the entire horizon window, weighting the earlier time samples in the 2 to 5 second time frame more highly.

Wind – Wind Farm Controller – FFR / POR Trials

Background

Wind Farm Power Stations (WFPS) can currently provide frequency response by feathering their blades to reduce the output. Then there is a difference between the maximum output available and the actual output of the WFPS. This difference can be utilised by the WFPS to increase its output when the system frequency falls. When the WFPS is in frequency response mode it automatically increases its output to a drop in system frequency and therefore reduces this difference. For WFPS to provide FFR or POR they must be in frequency response mode and be available.

Operational Complexities

Frequency response Services being provided from Wind Farm Control (WFC) introduces a number of complexities, which are explained below.

Available Active Power Signal Error

A calculation of Available Active Power (AAP) is provided by all WFPS to the TSOs as a real-time signal. This signal is a calculated value based on wind speed and pitch angles of turbine blades. Therefore the real-time signal contains some error. WFPS are monitored and required to keep the error in this signal below 6% Normalised Root Mean Squared over a fourteen day rolling period to ensure accuracy of information in real-time operations in the control centre. This monitoring is carried out using fifteen minute metered data and average AAP over fifteen minute windows. If a WFPS is providing operating reserve Services from its WFC, this will increase the need for accuracy of the real-time AAP signal. Reasons for this are:

1. Settlement of POR and FFR Services are based on availability. Availability for a WFPS is calculated as the difference between their AAP and MW output. Error in the AAP signal can result in over payment,

2. Performance monitoring of response for POR and FFR may be based on the difference between the AAP and AMW output prior to an event. The unit may not appear to provide the actual response expected if there is an error in the AAP signal. In this case the difference between AAP and MW output is assessed over a much shorter timeframe, and therefore the error in the signal becomes more significant.

Finding 3 - Calculation and Application of an Available Active Power Error Factor for WFPS units

Consideration should be given to calculating an error factor for WFPS units providing reserve Services. This error factor would feed into assumptions of when the unit is available to provide the Services and the performance monitoring of the Services.

It is suggested that this error factor could be calculated based on absolute 95th Percentile Error recorded for each WFPS unit multiplied by the Percentage Skew times 2.

$$\textbf{AAP Error Factor} = \mathbf{95^{th}}\ \textbf{Percentile Error (MW)} \times \frac{\text{Skew (\%)}}{100} \times 2$$

The error factor would be calculated quarterly based on the most up to date information available to the TSOs.

Skew (%) refers to, on average, how often the error is biased such that AAP is greater than AMW.

Variance in Available Active Power during events

Unlike conventional units where the available maximum output of the unit can be assumed to be constant over the period of a system event, the AAP of a WFPS may change over the event timeframe depending on wind resource.

Currently performance monitoring assesses a unit's response based on their pre event availability, taken as an average over the 30 to 60 seconds before an event. However, given the variability of wind, this assumption may no longer be valid. Failing to recognise and account for this variability could result in the following:

1. A WFPS being penalised for failing to provide the correct response at times when the wind resource has dropped, or alternatively a WFPS being rewarded for providing the correct response, when the response was only achieved through an increase in wind resource and not performance of the WFPS; and
2. The TSOs relying on a Service which may not be available in the quantities forecast prior to the event.

Finding 4 - Calculation and Application of a Wind Resource Variance Factor

To account for potential short term variances in availability, it may be appropriate that a WFPS should only be considered available to provide FFR, POR and SOR when its calculated headroom is greater than 5% of the unit's Registered Capacity. For TOR1 this value would be increased to 10% to account for the longer time frame.

Performance Monitoring of Wind Farms (WFC) response to events

There are a number of learnings on how to best performance monitor provision of this Service from WFPS:

1. Application of discounts applied to assumptions on availability of WFPS may also be applied as tolerances for performance monitoring. This would mean a WFPS would only be required to achieve up to their expected response minus these tolerances.

2. The calculation of pre event availability 30 to 60 seconds prior to an event may not be appropriate for WFPS, given the variability in the Available Active Power. This timeframe should be shortened to between 2 to 10 seconds prior to the event.

3. At times where the Available Active Power decreases during an event below tolerance levels, this could be accounted for within the calculation of a unit's expected response.

Finding 5 - Considerations for the Performance Monitoring of WFC Response

The performance monitoring of WFC response to a reserve event should consider taking account of variances that may occur in Available Active Power during an event by:

• Applying tolerances also applied to assumptions on availability

• Reducing the pre event time to between 2 to 10 seconds

• Accounting for wind decrease in the expected response at times when the AAP drops off below associated tolerances.

Forecasting of Availability

Technical availabilities of conventional providers of operating reserve Services do not change often, particularly close to real time. Given this, the TSOs have traditionally assumed that a conventional unit declared for 10 MW of POR currently would still be available for 10 MW in four to six hours' time, unless they were scheduled differently. This practice has historically been relevant and prudent, with the occasional exception due to plant malfunction.

For WFPS, this certainty of availability is not there given the variability of the resource providing it. Forecasting of reserve or ramping Services from WFPS' requires the following to be predicted:

1. What the Available Active Power of the WFPS will be, and

2. Whether the WFPS will be dispatched down.

Whether a WFPS is dispatched down is at the discretion of the TSOs and, therefore not considered possible for a WFPS to predict. However, forecasting of Available Active Power is within the capability of a WFPS.

From assessment of the data a number of observations can be made:

1. Overall, margins of error associated with the forecasting were large.

2. Comparison of error against registered capacity is not an appropriate metric as it inherently results in lower errors during low to moderate wind conditions.
3. Larger forecasting windows produced greater errors, albeit errors over all horizon windows were large.
4. Accuracy forecasting abilities differed significantly across all four providers. This highlighted the difficulties some providers had in establishing good forecast techniques and process whilst also showing higher accuracies are possible but will require time and effort to produce.
5. A cumulative approach to forecasting (summation of errors over a forecast horizon compared to actual Available Active Powers summated) appeared to be the most appropriate approach to analysis of forecast errors.
6. Trends could be seen between on the cumulative forecasts between low wind days and increased forecast error percentages.

During low wind times, WFPS are less likely to be curtailed and therefore the errors experienced at low outputs have less bearing on scheduling assumptions. As a result, it may be appropriate for the forecasts to discount these low wind times.

Finding 6 - Availability Forecasts from Variable Technologies as a Component of Performance Scalar

The TSOs should consider that variable technology types be required to forecast their availability of Service provision at least four hours ahead of real-time to allow the TSOs to schedule service availability accurately in real-time. Service Providers would be allowed lead time to adapt to these requirements.

To incentivise this, the DS3 System Service Performance Scalar could focus on two components in future:

• Scaling Element based on a unit's response to system events (PE), and

• Scaling Element based on a unit's availability forecasting accuracy (PA).

The overall DS3 Performance Scalar would then be calculated as:

DS3 System Services Performance Scalar = PE x PA

Specifics of how each forecast would be evaluated and what would need to be provided by Service Providers would be specific to each technology class.

Finding 7 - Considerations for the Assessment of WFC Availability Forecasts

Consideration should be given to evaluating WFC forecasting accuracy on a cumulative basis, by summing the errors over all trading periods when the Available Active Power exceeds 20% of the unit's Registered Capacity.

Interactions between Grid Code and System Services Requirements

WFPS are currently tested as part of their Grid Code compliance requirements. It is proposed to use these tests as the basis of determining if a WFPS – Wind Farm Controller response is eligible for reserve Services. Specific constraints and assumptions on this are;

1. Determining sub-two second response times given most of these tests have been carried out using 100 millisecond (ms) data and determining quantities of provision expected over the two to ten second FFR horizon.

2. Should a WFPS request to provide a response mode which effectively contradicts its current operational requirements within Grid Code. This may be caused as a result of units providing higher sensitivity droop response capabilities.

Point 2 in particular requires further consideration by the TSOs. System Services are effectively incentivising response characteristics through a number of product scalars. However, this behaviour may conflict with what the technology is required to provide under Grid Code. Further consideration is required as to what is the correct approach to take where conflicts arise.

Finding 8 - Impact Assessment of Grid Code Interactions

It is a finding of the 2017 QTP that an impact assessment of interactions between requirements for service provision under Grid Code and DS3 System Services may be beneficial in order to identify conflicts and recommend appropriate actions if any arise.

Wind – Emulated Inertia Response – FFR / POR Trials

Background

In addition to Wind providing frequency response through offering headroom, they can also provide a response through the provision of Emulated Inertia. This is often also known as “Synthetic Inertia” or “Inertia Emulation”. However, it is not to be confused with the DS3 System Services Synchronous Inertia Response as it is in fact considered provision of an operating reserve service to the TSOs (primarily FFR and POR). This is done through controlling the kinetic energy stored within the rotating masses within the turbines, effectively slowing them down momentarily, in response to a frequency detection and control system, resulting in a short burst of increased power output. However, following the triggering of this type of response the wind farm will in turn need to recover this additional energy.

This provision of Emulated Inertia is in addition to the Wind Farm Controller response provided. The response of emulated inertia is provided within the drive train of the turbines themselves and as such there is not believed to be any interactions between the ability to provide reserve services from WFC and Emulated Inertia whilst both are responding. However, post response timeframes of Emulated Inertia (recovery timeframe) interactions will be evident.

Operational Complexities

Interactions between Grid Code and System Services Requirements

Results from the trials have shown that a wind farm can only provide both EI and WFC response together as long as the duration of the EI response remains active. After this point the units will enter into an energy recovery which in turn impacts on its ability to provide WFC response.

Finding 9 - WFPS Providers of Emulated Inertia to Only Contract for WFC up to the Same Horizon Window

It is a finding of the 2017 QTP that consideration should be given to WFPS providers of Emulated Inertia not being permitted to contract for WFC for subsequent horizon windows; this is due to the fact that a response provided through Emulated Inertia effectively results in a unit entering a recovery mode.

In addition to this, the provision of EI and WFC in tandem effectively results in two separate Services being provided by the 1 providing unit for 1 System Service. Both of these Services have differing capabilities in relation to frequency triggers, energy recovery and more. Given this it may be necessary to treat the provision of both of these Services separately such that:

- Separate parameters for Product Scalars may be associated with each element of the service – EI and WFC,

- Performance Monitoring could identify the expected response of each component, EI and WFC, and assess an overall response in accordance with the combined required response, and
- Settlement could calculate the available volumes of each component separately.

Finding 10 - Application of Separate Product Scalars to the Provision of EI and WFC by WFPS Units

Consideration should be given to the application of separate System Service product scalars to providing units that deliver a Service using two mutually exclusive mechanisms combined i.e. Emulated Inertia and WFC. Each separate product scalar would account for that component of the providing unit's capabilities.

Energy Sustainability and Recovery of EI

Under the FFR Service definition there is a requirement that a unit cannot reduce its energy produced in the ten to twenty second window than it put in during the response horizon window. From assessment of responses seen during the trials for emulated inertia, there appears to be times where this criterion has not been met, but also times where it has been achieved. From discussions with trialists, the achievement of this requirement was heavily dependent on the WFPS power output at the time of the event. In addition to this, trial participants have also provided data on a new software upgrade to their turbine designs which effectively allows them to control the speed at which this recovery takes place, effectively meaning they can tailor how quickly they recover energy.

Separate to this is the ability of the units to sustain their response across service horizon windows. During the trials, results did not appear to show any event where the unit exceeded the fifteen second response associate with POR. As a result, it is proposed that EI is not considered as proven for any service window longer than this.

Finding 11 - EI to be Considered Proven for FFR and POR time horizons

Consideration should be given to wind farms providing Emulated Inertia being eligible to contract for both FFR and POR. However, this would be contingent on their compliance test demonstrating a response for the entire horizon window of POR.

Certainty of Availability

As discussed already, wind is a variable technology and it is therefore proposed that forecasting of availability should be provided. For an EI response, it is suggested that this forecasting would focus on the unit's ability to forecast where they are on their reserve curve.

For EI, a wind farm will effectively provide a response once their megawatt output in real-time is above a certain threshold, usually about 20-25% of their Registered Capacity. When assessing forecasting however, it is only important to assess where the forecast sits within the unit's contracted reserve curve.

Figure 3 shows an example reserve curve for EI. A wind farm would need to predict which region of the curve it will sit in on average per trading period (i.e. Regions A, B, C or D). This can be calculated from the submissions of Available Active Power provided for WFC purposes and a pass or fail awarded for each trading window the wind farm has effectively predicted which window they sit within in real-time.

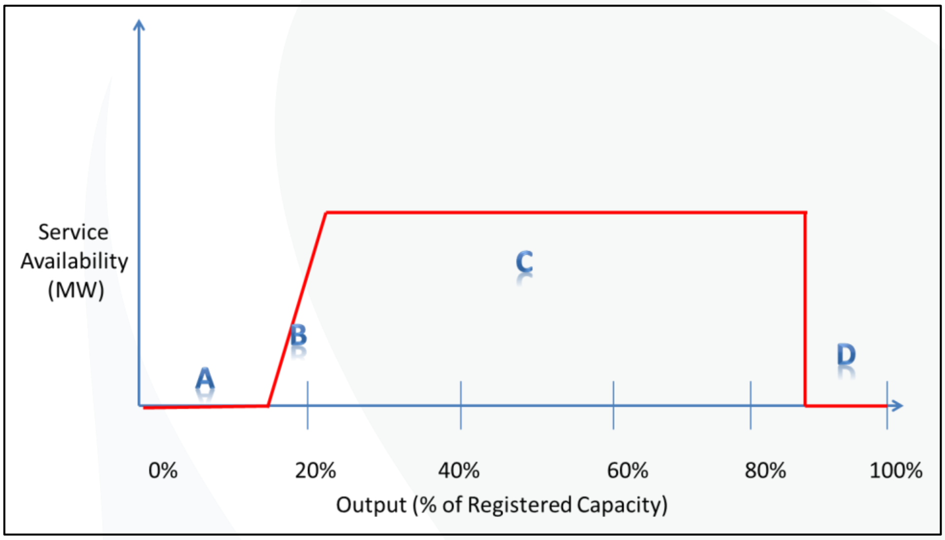

Figure 3: Example of a WFPS Emulated Inertia Reserve Curve

Finding 12 - Considerations for the Assessment of EI Availability Forecasts

It is a finding of the 2017 QTP that the evaluation of the accuracy of the forecasting of Emulated Inertia from wind could be based on the imposition of AAP forecasts on to reserve curve parameters and assessing the unit operating in this region in real-time.

New Signals required for Control of Emulated Inertia

Most new technologies may require additional real-time signals in order to provide System Services. These signals would be required for controllability and visibility of Service provision purposes primarily. For the provision of EI the following signals may be appropriate:

1. **On /Off Control** – The ability for the TSOs to enable / disable the Service.
2. **Service Availability Declaration** – This signal calculates in real-time what the megawatt availability of the Service provision is expected to be.

This should account for the number of turbines available, wind speeds at each turbine, the units contracted reserve curve parameters and any limitations caused by Maximum Export Capacities. In effect, this signal is calculating to the best of the provider's ability the megawatt response they would expect to provide should an event occur at that moment in time.

This signal would replace in effect the need to declare Service provision via EDIL as is currently done and would be required for each DS3 System Services being procured by WFPS Emulated Inertia (i.e. one for FFR and one for POR).

Finding 13 - New Signals to Manage Service Provision from New Technologies Being a Minimum Requirement to Receive a Contract

It is a finding of the 2017 QTP that consideration should be given to mandating that the installation of new signals to manage System Service provision be part of the minimum compliance standards within DS3 System Service contractual arrangements. Specifics of the additional signals required for each Service Provider would depend on their technology class / sub-class and the Services they wish to provide.

High level descriptions of what new signals may be required for each new technology class are described within each technology's section of this report.

Compliance Testing of Emulated Inertia

Compliance Test procedure are required for System Services more generally. These test procedures demonstrate the capabilities of providing units and are used to identify contractual parameters for Services. Existing technologies or Service Providers have well established test processes for justifying these parameters more generally. However, for technology classes or sub-classes that traditionally have not been providers of System Services, new test processes would need to be created.

Finding 14 - New Providers of System Services to have completed a Compliance Test in order to get a Contract for System Services

Consideration should be given to a rule that all Service Providers must have undertaken a compliance test in order to prove they have met the minimum compliance requirements for System Services. These test processes would be technology-class specific in general, with different tests and requirements also required to justify individual services and product scalars in some cases.

High level details of what each test process may entail are described within each technology's section of this report. Final test procedures would be published in advance of the next procurement process.

For Emulated Inertia, it is suggested that the following be considered in the development of the test process:

1. Testing is limited to the availability of the wind resource on a given day. As such it is not possible to demonstrate response over the entire operating range through testing.

   A possible solution to this is to carry out a test only when the wind resource is in the region C shown in Figure 3 above and use this to demonstrate capability over a minimum operating range (for example, assume the service is available at this quantity when operating at greater than 25% of the units Registered Capacity and not available below this. Data from Performance Monitoring showing responses below this region could then be used to justify an increase in the capability range.

2. In addition to this testing needs to be able to determine the following parameters:
   a) The rise time of the service if providing a sub two second response for FFR,
   b) The contracted volume of FFR and or POR demonstrated as the minimum response provided over each horizon window,
   c) The maximum time the response can be sustained for,
   d) Is the energy absorbed in the recovery period less than the energy input over the FFR horizon.
3. Additionally, as the wind farm will effectively be providing this Service following the detection of a drop in frequency it is important to test does the Service activate at this trigger point and not before it.
4. In many cases these devices also have the capability to adjust their frequency proportionally in response to a change in frequency (similar to a droop response), as well as stop responding once the frequency recovers beyond a certain point. These capabilities should be considered as part of the testing process also.
5. Due to possible interactions between IE and WFC this test would be undertaken in isolation of WFC, which should be disabled during the test.

Impacts of Energy Recovery on Dynamic Provision of the Service

Traditionally, dynamic service provision has come from conventional thermal units that can constantly provide frequency regulation without any limitation of energy charge. Therefore, the impact of charge limitation on the dynamic provision of service has never been assessed to date by the TSOs, with the TSOs effectively assuming providers had no stored energy limitations. For Services such as EI from wind, assumptions such as this no longer hold true. This has an impact on how the TSOs schedule service provision going forward.

In considering the likely impacts, the TSOs considered 2 types of energy limited devices:

1. Energy Limited Devices with Energy Recovery Control - These units can only respond for a fixed duration before they have exhausted their resource. Following this however, the unit can subsequently delay its energy recovery / recharge until after the system frequency has recovered. In addition, the unit can also control their rate of recovery.
2. Energy Limited Devices without Energy Recovery Control - These units must recover energy immediately following provision of a Service and / or depletion of its resource.

For scheduling of Services, units that can control their recharge have greater value to the TSOs. Effectively, those that cannot will result in the TSOs carrying additional reserve volumes in other service windows to compensate for this energy recovery. Given this, the TSOs consider that it may not be appropriate to allow devices that cannot delay their energy recharge to receive the enhance Product Scalar for dynamic provision of the Service.

EI, as it is currently provided, cannot control its energy recovery and as such is only considered as a static provider of reserve Services.

Finding 15 - Classification of Energy Limited Devices without Control of their Recharging as Static Providers

It is a finding of QTP 2017 that consideration should be given to classifying certain energy-limited devices as static providers of operating reserve Services. This would apply to units that cannot sustain dynamic provision of Service and also cannot control their recharge.

Energy-limited devices that must recharge their resource immediately following their response can cause a reduction in the overall volume of Services available in further horizon windows as these devices will be recharging during these times.

Performance Monitoring of EI

From assessment of the provision of EI to events, a number of learnings can be obtained in relation to performance monitoring;

1. It may be appropriate that the expected response is based on an increase in the unit's pre event output solely. Any drop off in Available Active Power would be considered under the performance expected of the WFC Service component.
2. The sustainment of the response over the entire horizon window is most difficult to achieve for EI, as such it may be appropriate that the entire horizon is assessed rather than an initial assessment.
3. It may be appropriate that the recovery within the 10 to 20 second post event also forms part of the overall assessment. It is suggested that performance here should account for up to 50% of the overall response performance.
4. It may be appropriate that assessment of the post event recovery accounts for where the Service Provider has stopped responding in the FFR timeframe due to the system frequency recovering. It is proposed that the provider is to be required to sustain a response greater than 5 seconds in order for criteria c) to apply.
5. It may be appropriate that the pre event time frame be calculated closer to time zero of the event. An average over two to ten seconds before an event is considered more appropriate for these Services.

Finding 16 - Considerations for the Performance monitoring of EI

Consideration should be given to focusing performance monitoring of Emulated Inertia on the ability to sustain the Service over the entire horizon and the recharge window. Additionally, the pre-event output would be calculated closer to the time of the event due to the variability of the resource providing it.

Demand Side Management – FFR / POR Trials

Background

As part of the DSM trials, 2 operational Demand Side Units (DSUs) were contracted to provide operating reserve Services. The DSUs provide this response by controlling an aggregate of individual demand sites (IDS) each of which can produce a reduction in system demand levels, either by turning down load on sites or using embedded generation to the same net effect. Currently, there are a number of DSUs registered in the energy market, where they provide dispatch-based Services similar to Ramping Margin 1. DSUs dispatch IDSs through a variety of mechanisms under this approach, notifying customers to turn down in some cases and implement direct control in others.

The provision of operating reserve Services from DSUs presents a wide range of technical complexities for the TSOs. Most of these complexities are based on two needs for provision of operating reserves;

1. The need for certainty of response, and
2. The ability to measure response in a manner which delivers confidence in responses provided.

Although only one provider was contracted for the FFR trial, both providers were able to demonstrate responses within the FFR through to TOR1. Neither DSU were made up of the minimum number of IDSs to be classified as ‘dynamic’ (10 steps minimum) although both trialists could demonstrate dynamic like behaviour, albeit with less steps.

The mechanisms in which both trialists were set up to provide reserve Services were different. One DSU was set up to give a completely static response, whereby they were set to a pre-agreed trigger point and responded fully once the system frequency dropped below this threshold. The other DSU was set up with a maximum and minimum trigger response point and were required to give a proportional response (similar to droop) over this range. Given that tripping load has an impact on the IDSs participating in the trials, it was agreed pre-trial to allow the DSUs to move the trigger points during the trials to ensure customers weren’t adversely impacted whilst learnings for the DSU operator were being achieved.

Operational Complexities

Throughout the trials, a number of operational complexities were identified for the provision of reserve Services from DSM. These are discussed in detail in this section.

Categorising Provision of Service

As part of the DS3 System Services Interim Arrangements, DSM providers were classified as dynamic if they could track system frequency across at least 10 discrete steps. This was a relatively simple approach. Through the Qualification Trials, a number of key parameters, as described below, were identified to assist in classifying the capability of a DSU.

Generic DSM Descriptor Parameter	Description of parameter
$F_{Trigger\ on}$	Describes the trigger point that the DSU is expected to start responding at.
$F_{Trigger\ Range}$	This sets out the frequency range over which the DSUs will go from minimum to maximum declared response. For static providers this is set to 0 Hz.
$F_{Trigger\ Off}$	This sets out the frequency at which the DSU (or IDS) will begin to cease responding to the Service
T_{Loiter}	This assigns a time delay to the $F_{Trigger\ Off}$ characteristic such that the DSU (or IDS) will continue response for a fixed period thereafter. This could be utilised to ensure all DSUs do not cease responding at one time, causing a frequency ripple if large enough.
$T_{Max\ On}$	This assigns the maximum time duration of response to which the DSU (or IDS) will respond during an event.
$T_{Min\ On}$	This assigns the minimum time duration of response to which the DSU (or IDS) will respond during an event.
$T_{Min\_Interval}$	This assigns the minimum time duration following a response before the DSU (or IDS) will become available to respond again.

Table 3: DSM Parameters and Descriptions

Depending on the DSU Control and Aggregation System (CAS) in use, different systems may not contain all of these parameters, or some may have equivalent parameters but use different naming conventions. For each of the parameters shown, the DSU may have an equivalent parameter associated with each IDS, i.e. a global or a local parameter. These values may or may not be the same. All items discussed below are in relation to global variables.

Based on these parameter sets, it is proposed that it may be appropriate to implement 3 categories of reserve provision from DSM, with an additional capability that is an enhancement of two of these categories.

Dynamic

Full dynamic provision means the DSU can constantly track system frequency and adjust its response accordingly. In order to be classified as this, the following criteria may apply:

1) The DSU must contain at least 10 discrete steps or sources which can dynamically adjust load contributions in response to frequency.
2) The DSU must have frequency measurement installed locally and
3) The DSU must have direct control of each IDS contracted.
4) The DSU must be capable of providing all the controls identified in Table 3.
5) The Global $F_{Trigger\ Range}$ must be adjustable over a range up to 2 Hz (4% Droop).
6) The Global $F_{Trigger\ Off}$ must be greater than or equal to the Global $F_{Trigger\ on}$.
7) The Global $T_{Min\ On}$ should be less than two seconds.
8) The Global $T_{Max\ On}$ should be at least equivalent to the Service the DSU is applying for.
9) The Global $T_{Min\_Interval}$ should be equal to 0 seconds.

Parameters rolled out on an IDS basis may contain different settings, but the overall portfolio may have to satisfy the criteria outlined above. This can be achieved by cycling of IDS responses as described in the tables below.

Stepped Static

Stepped Static response would be similar to the provision of dynamic response. However, the key difference is that Stepped Static would only be expected to respond proportionally to a drop in frequency. It does not have to subsequently reduce its response proportionally as the frequency recovers. In order to be classified as capable to do this, the following criteria may apply to the DSU:

1) The DSU must contain greater than one discrete step
2) The DSU must have frequency measurement and direct control of each IDS contracted.
3) The DSU must be capable of providing the Global $F_{Trigger\ On}$ and the Global $F_{Trigger\ Range}$ parameters.
4) The Global $F_{Trigger\ Range}$ must be adjustable over a range up to 2 Hz (4% Droop)
5) The DSU must then either be able to respond to recovery due to either Time or Frequency.
6) If responding to frequency the $F_{Trigger\ Off}$ should be at least the same as $F_{Trigger\ On}$
7) If responding to time then the Global $T_{Min\ On}$ should be at least equivalent to the Service the DSU is applying for.
8) The Global $T_{Min\_Interval}$ can be set up to 5 minutes.

Basic Static

Basic Static response is similar to Stepped Static with the key difference being that $F_{Trigger\ Range}$ would be set to 0 Hz so the unit provides its entire response at one single frequency trigger point.

In addition to the Static or Stepped Static response types, if a DSM provider can deliver what is referred to as a hysteresis effect, whereby the DSU can delay their recovery based on both a frequency point and a time delay, this additional flexibility may be rewarded as it has benefits to the system operator. This type of behaviour would require a DSU to be able to provide all of the response controls shown in Table 3 with the exception of $F_{Trigger\ Range}$.

Finding 17 - Consideration of the Classification of DSM Units as Static, Stepped Static or Dynamic Providers

It may be appropriate to consider further differentiating the various capabilities of demand side units in the provision of reserve System Services into static, stepped static and dynamic, with a dynamic response more valuable than a static response.

Forecasting of Availability

As part of trials, DSUs were requested to carry out forecasting of their availability on a week-ahead basis consisting of submissions of their expected availability for each trading period over the next week.

From assessment of data, both DSUs performed strongly in terms of ability to forecast their availability. One DSU retained their actual availability above 90% of what was expected for 91% of all settlement periods. The other DSU identified errors in the region of 20% on average for their week-ahead forecasts but also provided short-term forecasting three hours out with errors typically within 10% of what was forecast.

These results show that accurate forecasting of Service Provision by DSM can be achieved, albeit this predictability can be heavily dependent on the IDS' make-up of the DSU itself. Also, although these errors are in percentage terms, the actual declared available values were quite small during periods of the trials and hence the megawatt quantities of the errors were small.

Finding 18 - Considerations of the Assessment of DSM Availability Forecasts

It is a finding of this report that the evaluation of a DSU's forecast of reserve availability account for whether the DSU is providing the Service(s) or has been dispatched in the Energy Market. As a result, it would be proposed to only assess reserve forecasting for the period when the associated DSU has not been dispatched in the Energy Market.

In addition, both the evaluation of a pass/fail based on a trading period or based on a cumulative error approach would be suitable for the performance monitoring of DSM.

New Signals Required for DSM Reserve Provision

New technologies providing System Services may require additional signals. For DSM, the following signals are proposed;

1. **On /Off Control** – The ability for the TSOs to enable / disable operating reserve of the DSU as a whole. This would require the DSU to have direct control over each IDS to allow it to disable triggering of response at each IDS.

2. **Service Availability Declaration** – This signal would calculate in real-time what the megawatt demand reduction capability of the Service Provider is. The signal would calculate the actual availability of the Service Provider in real-time. It would take account of amongst other things:
    - Real-time load availability of sites,
    - Whether relays of IDS are enabled/ disabled, and
    - Any congestion management instructions issued to the DSU.

This Availability Signal would be provided for each of the DS3 System Services being procured by DSMs (FFR, POR, SOR and TOR1).

3. **Service Response Quantity** – This signal would calculate the response the DSU is providing for a given Service when triggered to respond based on the aggregation of load reductions seen across dispatchable loads providing the Service. At times when the unit is at maximum response to a Service this value would equal the service provision availability of each Service.

4. **Main Incomer Load Readings** – This signal would provide a summation of the actual megawatt load reading on each main incomer of the IDSs providing the response in real-time. Its purpose is to cross-check that the quantities calculated in c) generally align with actual reduction seen on the system. Over longer durations, this signal could also be compared to the aggregate of meter data to ensure overall energy readings are not biased, assuming the DSU is constantly available for too much / too little.

Testing and Compliance Test Procedures

Provision of reserve Services from DSM may require new test procedures and processes to be established to verify contractual parameters for DSM. Specific consideration would need to be given to the aggregate nature of DSM in any test process. At a high level, testing of DSM may consist of two elements:

1. **Individual Demand Site Test** – This would require Service Providers to carry out tests on each IDS, demonstrating details on pre-defined technical parameters of each IDS and the operation of the detection and control mechanisms installed at each site. This work would be the responsibility of the Service Provider to undertake. The TSOs may elect to independently verify the results of these tests on a subset of IDSs.

2. **DSU Central Aggregation System (CAS) Test**– This test would review the aggregation protocols used within the central controller of the DSU itself, ensuring that signals provided to the TSOs are calculated accurately. This test may also require the DSU as a whole to be

able to respond to a simulated frequency injection into their central controller to verify that the DSU can respond in line with its product definition, i.e. Dynamic or Static provision. The DSU may be required to make data on an IDS level available during this test.

Distribution Network Operators (DNO/ DSO) Approval Process

All Service Providers connected at distribution level require the written approval of their relevant DNO/ DSO in order to be eligible for System Services contracts. DSUs provide a logistical challenge in this regard as the DNO/ DSO require assessment and approval of each IDS.

There is already a process for managing congestion management issues on the distribution network relating to the energy market. From initial discussions with the DNO/ DSO it is likely that a similar process will apply to System Services. However, there are distinct differences between current congestion management processes and approval of System Services such as:

1. Currently DSUs are paid for the availability of a site in the energy / capacity market irrespective of whether the site has a binding instruction set or not. Service Providers will be paid based on actual dispatchable availability, i.e. the DSU must discount this availability from their portfolio in real-time.

Note: An instruction set refers to the notification process used by the DSO / DNOs whereby they notify the DSU whether an IDS site is allowed to provide a Service, or not and over what time horizons the instruction is binding.

2. Given the short term nature of some of the System Services and the combined nature of reserve responses, it is possible that the DNO / DSO may wish to apply differing instruction sets to different Services.
3. System Services approval process timelines may be dictated by procurement timelines
4. Given point 1 above, the need for certainty as to whether an instruction set will change overtime becomes of more significance.

Finding 19 - Consideration of the Establishment of Defined Processes to Approve Provision of Services from Distribution-Connected Units

Consideration should be given to the establishment of a clear and transparent process for the approval of distribution connected System Service Providers. Where possible, this process would give as much certainty to the DSU as possible in terms of forecasting their likely congestion going forward, even if this required the process to be more restrictive.

As an output of the DNO / DSO approval processes, it is likely a DSU will be approved (or not) to provide certain System Services. However, specific IDSs within the DSU may have instruction sets associated with them not allowing them to operate during certain times.

In this instance, whether the TSOs should contract with a DSU or allow the DSU to include those IDSs as part of its overall portfolio needs to be considered. The TSOs propose to allow all IDSs that have been approved by the DSO / DNO to form part of the overall portfolio, irrespective of whether this approval includes some form of an instruction set associated with it.

It is then the responsibility of the DSU to enable / disable response of these IDSs during times the instruction set becomes binding, and also account for this reduction in their declared availability of Service provision. There are a number of reasons for this:

1. Instruction sets may only apply during certain time periods meaning the IDS may be available to provide Services (albeit at a more time constrained basis),
2. Instruction sets applied by the DNO/ DSO may change following review from time to time, hence ruling an IDS out of provision of System Services at a point due to an instruction set would result in constantly removing (or adding) IDS' from the overall make-up of the DSUs' contractual arrangements,
3. It is expected that instruction set processes may become more granular overtime, with instructions issuing closer and closer to real-time. The TSOs fully supports this vision and in this environment, it would be inappropriate to rule an IDS' out when contracting due to an instruction set which is changing constantly.

Certification Process for DSUs – Managing the Portfolio

Any generating unit connecting to the power system to provide a System Service will have gone through a connection offer process. This is a well-established process through which details on technical characteristics of the generating unit for both energy and System Services are identified. For DSUs, the Operational Certification process is used to capture this information. However, this process currently only provides details on energy market characteristics of the DSU.

Given the aggregated nature of DSM, it is important to have processes in place for certification and verification of contractual parameters for the constituent parts of the DSU. It is conceivable that any of the following could occur in managing DSM, some of which the TSOs believe to be acceptable and some not:

1. An IDS could be contracted to provide System Services as part of one operational DSU and Energy under another.

   Conceivably, 1 DSU could be dispatched in the energy market and as IDSs within that DSU are also providing System Services, the amount of reserve headroom for example could decrease due to this operator action. Visibility of these interactions would be difficult to foresee and manage in the control centre. Therefore, it may be appropriate that any IDS be contracted with only one DSU for both System Services and energy demand reduction.

   This does not mandate that a DSM provider would need to be a participant in the energy market itself, but it would require the provider to be certified in line with the current DSU operational certification process itself. Whether a DSU needs to participate in the energy market or can solely provide Services is considered an open question at present and outside the remit of this trial.

Finding 20 - Consideration that an IDS can only be Contracted with 1 DSU for Provision of both System Services and Energy

It is a finding of this report that it may be appropriate that an Individual Demand Site could only be contracted with a single DSU operator to provide both System Services and operate in the Energy Market. Further consideration may need to be given as to whether this represented a barrier to entry to either market.

2. DSUs having a separate portfolio of IDSs for System Services than those who provide energy / capacity market.

   Although the TSOs consider that it may not be appropriate for an IDS to contract with multiple DSUs, we do not believe an IDS must contract with a DSU to provide both energy and Services. Conceivably, certain IDSs such as refrigeration plant are well suited to the provision of short term Services but would not participate in long term responses such as ramping. The TSOs support the concept that a DSU would provide different Services from different portfolios as a technically preferable solution for the system overall.

   However, there are two constraints to this approach. Firstly, the TSOs may not have visibility when dispatching a DSU in the energy market as to what impact this may have on their availability for operating reserves. Secondly, this could have potential interactions with the payment rules for the higher of the Physical or Market Dispatch position. As a result, any flexibility in respect to the DSM portfolio itself must be taken with this in mind.

Finding 21 - Consideration that DSUs Should Have Flexibility to Distribute their Portfolio of IDSs across System Services and Energy

Consideration should be given to the principle that a DSU be able to provide System Services and Energy Services from different portfolios of IDSs should they wish to do so. However, the TSO would require visibility of the interactions between these Services and as a result this may limit this flexibility to some extent.

The DNOs may only approve an IDS to provide certain Services.

3. Different technical parameters / control mechanisms being applied by the DSU to different Services. For example, the DSU may elect to control a reserve Service with the automated switching of a relay, but may elect to respond to a dispatch instruction by notifying a customer and requesting them to turn down.

Given all this potential for complexities, it is important to have a well-structured process for managing and verifying the composition of DSUs. The current Operational Certification process is well-established and provides the TSOs with confidence in the abilities of a DSU. The TSOs believe that this process should be built upon to incorporate certification of System Services as well as energy provision. This helps to ensure interactions between reserve Services, which are automated and dispatch-based Services are accounted for. In addition, by expanding an existing process, this incorporates all the benefits which have been achieved through the continuous improvement and refinement of the process to date, rather than starting from scratch with a new process.

Finding 22 - Expansion of the Operational Certification Process for DSM Units

Consideration should be given to the expansion of the existing TSO Operational Certification process to capture certification of System Services from all DSM providers.

Performance Monitoring of DSUs

At a high level, it is suggested that the performance monitoring of DSUs for static or stepped static providers should focus on whether a DSU has achieved at least what was expected, based on the difference between their availability signal for each Service and the megawatt response shown.

For fully dynamic providers, it is suggested that performance should focus on the difference between their expected response and their achieved response, i.e. an average error assessment. This assessment should account for the time-delay of response of sites using a delay factor parameter associated with the DSU.

In addition to the performance monitoring of the DSU response to events, additional steps may be taken from time to time to ensure accuracy of the data provided to the TSOs. Details on some of these approaches are contained in the Measurability section of this report.

Synchronous Compensator and Flywheel Hybrid (ESU) – FFR / POR Trials

Background

The synchronous compensator implemented as part of the trials consisted of a small synchronous generator connected to a flywheel to add mass and therefore kinetic energy. As such the unit is capable of providing inertia to the power system. The device can also be connected via either a synchronised connection to the grid or it can be electrically isolated via back to back inverters. When electrically isolated from the grid the unit can use its controller to provide Fast Frequency Response in a controlled manner by reducing the speed of the flywheel and transferring this kinetic energy into electrical energy in the process.

When in normal operation this device is reliant on pulling energy from the grid in order to increase its rotational speed up to synchronous speed and as such a small amount of load is absorbed to account for losses. However, when responding to FFR, unlike with a thermal unit where the pickup in output is provided by increasing fuel input, the synchronous compensator can only provide the response until all the kinetic energy stored in the device has been discharged. In this manner the device can be considered similar to an Energy Storage Unit whereby it has discharge limitations.

Operational Complexities

Interactions between provision of SIR and FFR

Due to the control design of the synchronous compensator operating as part of this trial, in order for the device to provide FFR it was required to be connected via back to back inverters. In such instances the device would become unavailable to provide SIR during times it was providing FFR. The control system of the unit is designed in such a way that the unit can remain synchronised (hence providing SIR) until such time as an under frequency trigger is breached. Whether the unit is considered available for both Services and how this is controlled needs to be considered.

In addition to the performance monitoring of the DSU response to events, additional steps may be taken from time to time to ensure accuracy of the data provided to the TSOs. Details on some of these approaches are contained in the Measurability section of this report.

In general, there are interactions between different Service categories and units are paid based on their technical availabilities to provide these Services. If a unit is available for 10 megawatts of POR as well as 30 megawatts of Ramping Margin 1, the unit is paid for availability of both, with the availability for providing 1 reduced subject to being dispatched to provide another in real-time.

However, certain Services such as SIR are not based on technical availability but rather based on a unit being dispatched to provide the Service. Due to this, if the provision of another System Service impacts on a units ability to remain synchronised to the system providing SIR then the TSOs are of the view that the unit should not be considered available to provide both of these Services.

Finding 23 - Interactions of Provision of Reserve or Ramping Services not to Impact on a Provider's Ability to Deliver SIR

It is a finding of QTP 2017 that if the provision of another System Service impacts on the ability of a provider to deliver SIR, then the unit may only be considered available for one of these Services.

WFPS and Sync Comp Hybrid Interactions

Throughout the trials no interactions were shown to occur between the WFPS and the Synchronous Compensator. Given that both components of the unit are electrically separated behind their connection point it is proposed that both components of the hybrid be treated as separate units in terms of Performance Monitoring and Settlement.

One thing that will be important to ensure when assessing the response of hybrid units is that the overall response assumed available by each component of the hybrid does not exceed the overall maximum export capacity of the unit as a whole.

Testing of Services

Test processes for Energy Storage Units may need to be designed to acknowledge the following:

1. Frequency Controller Accuracy - For non-governor controlled units it is important to assess their triggering accuracy.
2. Energy Discharge Limitations.
3. Droop responses – how to test for unit capability to provide a range of droop capability. Each droop would need to be tested and verified.
4. Time Delay factors between frequency detection and provision of response.
5. Other enhancements to capability driven by product scalars such as sub-2 second responses or controlling the energy recovery of ESUs.

Parameterisable Frequency Response Curves

The TSOs are minded to implement parameterisable frequency response curves to define the provision of FFR. Depending on whether the unit is classified as dynamic – as opposed to static – the TSOs may incentivise the unit, through the Product Scalar for the Enhanced Delivery of FFR, to have the capability to provide a higher sensitivity droop in response to frequency events.

This capability to provide higher droop settings offers greater flexibility to the TSOs to ensure devices provide their maximum capabilities at times when they are most needed. This capability is most important at times of very low system inertia when the system frequency suffers a significant drop. During these times, the frequency nadir can occur very quickly, close to or even sub one second potentially. To counteract this, fast response provided by units with frequency control is required. If such units are designed to respond with higher sensitivity droops, they must be able to act with close to zero second responses to ensure they are not effectively ramping their output to a frequency event which has already experienced its nadir and entered into its recovery mode.

As a result of this, it is proposed that it may not be beneficial to the system to incentivise units whose response time is longer than 1 second to respond with higher sensitivity droops. Additionally, it is suggested that aggregators should not be allowed to provide this type of Service at this point given the stepped nature of their response.

Finding 24 - Incentivisation of Higher Sensitivity Droops Only to be applied to Units with Sub 1-second Response Times

It is a finding of QTP 2017 that units that are unable to deliver the FFR Service faster than 1 second may not be incentivised to provide higher sensitivity droops in response to frequency events.

Forecasting of Availability

It is proposed that storage devices be required to provide forecasts of their expected availabilities. This should take account of the actual response given, such that if the device is not available due to giving a response to an under frequency event then this should be accounted for.

New Signals Required for the Service

Similar to the other Service Providers, it is suggested that ESUs be required to install a number of new signals in order to provide the controllability and visibility which is needed to operate them. With this in mind the following signals / controls may be required for the provision of reserve Services from ESUs, in addition to the current basic signals requirements for Power Park Modules:

1. **On /Off Control** – The ability for the TSOs to enable / disable operating reserve.
2. **Service Availability Declaration** – Similar to as discussed in previous sections.
3. **Charge Remaining (%)** – This signal notifies the TSOs of how much charge is remaining in the Energy Storage Unit.
4. **Parameterisable Droop Response Control** – This signal effectively provides the TSOs with the ability to change a unit's droop settings within the range set out in the System Services contract.

In practice, this will likely work by identifying a number of predefined curves and sending a command to switch between these curves.

Performance Monitoring of ESUs

Similar to approaches discussed within the DSM and Emulated Inertia trials, it is suggested that ESUs be assessed using a similar approach over the entire Service window and subsequent recovery periods where applicable.

An assumed time delay factor identified through the compliance testing process would be required for assessment of droop responses in particular. This value sets out the time after which a unit has triggered beyond its predefined point that it is expected to start responding.

HVDC Interconnectors – FFR Trials

Background

HVDC interconnectors already provide POR, SOR and TOR1 to the TSOs. Hence, this trial was specifically focused on proving the technology class is capable of response times in the FFR timeframe. During the trials the two interconnectors were set up to respond to FFR.

Operational Complexities

There are no major operational complexities associated with the response of HVDC Interconnectors. A number of more general learnings with respect to performance monitoring were found during the trials:

1. **Time-delays for Frequency Controller Device**s - Non governed controllers effectively detect a fall in system frequency and send a signal from their controller for the unit to respond proportionally. There is a time delay associated with this detection and response. Performance monitoring currently assumes this response time is non-existent (i.e. an ideal governor control). However, as providers begin to produce greater proportional response (higher sensitivity droop) then this time delay becomes more pronounced in terms of performance monitoring. It is suggested that this should be considered for performance monitoring of operating Services delivered by interconnectors and similar technologies such as ESUs going forward.

2. **Loss Factors on Interconnectors** – Due to losses on the interconnectors the actual response obtained may be skewed slightly depending on the losses which occur across the interconnector. In general, units currently account for this through the use of Export adjustment factors. However, in the case of interconnectors these losses may be quite significant. One way to protect this would be to assess the measurement on the connection point of the interconnector with the other system and agree in principle on static loss factors.

Finding 25 - Consideration of the Use of a Time Delay Factor in Performance Monitoring

Consideration should be given to the use of a time delay factor in performance monitoring of frequency controlled Services by fast acting devices, or those with higher sensitivity droop equivalents.

CDGU – FPFAPR/DRR Trials

Background

The CDGU trial for FPFAPR / DRR is essentially assessing the fault ride through capabilities of synchronous machines to firstly remain connected during a fault and secondly to provide immediate fault current injections following a fault.

Through operational experience, it is assumed that synchronous machines inherently give this type of response immediately following a voltage disturbance. However, in order to contract with Service Providers for the Service, it is suggested that performance monitoring and standards should be in place to ensure units are responding accordingly.

Operational Learnings

Faults on the network are common in general; however they are locational specific and as such the regularity of faults occurring locally are small. In addition to this, unlike a frequency injection test for reserve Services, there is no simulated test that can be applied to the FPFAPR / DRR Services on the actual power system; this means that in "Data Poor" scenarios the use of testing cannot be applied as a metric to assess a unit's performance.

Given this, it is suggested that a monthly performance scalar may not be appropriate for the FPFAPR / DRR Services at this time. Rather, when an event occurs, the performance of the unit should be assessed and engagement between the Service Provider and TSO take place to identify and fix any non-compliance issues. Subject to this not being done, the TSOs may look to reduce or revoke payments of the Service Provider accordingly.

Finding 26 - Consideration that Performance Scalars not apply to the provision of FPFAPR and DRR

It is a finding of this report that a performance scaling element may not be appropriate for the FPFAPR / DRR Services, but that the Services could be assessed from time to time in line with the compliance requirements of the contract.

Consideration should be given to what is the most effective way to prove these Services going forward. Based on the trial learnings, it is proposed that other methods are considered to prove the Service. One way of doing this may be to pull data from historical fault records where available to build up an understanding of the technologies' capabilities more generally.

Wind – FPFAPR/DRR Trials

Background

The WFPS trial for FPFAPR / DRR is essentially assessing the fault ride through capabilities of this technology class in a shorter timeframe than is required in Grid Code. Unlike synchronous machines, these types of units do not provide immediate fault current injections inherently following a fault. However, via detection in their controllers, generally through the use of a Phase Locked Loop, these units can detect a voltage dip and respond in a very short timeframe.

Operational Learnings

Given the lack of events data, similar to the CDGU trials, the TSOs is minded to consider alternative mechanisms to develop a better understanding of the operational complexities and provision of these Services going forward.

Measurability of 'Fast Acting' Services

This section of the report assesses the requirements needed to be able to measure Services, in particular the three "Fast Acting" Services. The section will focus on three key questions:

1. What quality of data is required to be able to measure response of technologies?
2. How to ensure these standards are being adhered to by third party providers?
3. Are there any additional requirements needed for aggregators and /or hybrids?

1. Data Requirements

The purpose of this section is to set out the minimum data requirements required by the TSOs in order to be able to measure Services, focusing in particular on the fast acting Services. This minimum standard is based on a number of principles:

1. It is in Service Provider's interest to install adequate measurement equipment in order to performance monitor their responses accurately.
2. The use of a minimum standard attempts to strike a balance between guaranteeing a relatively high level of accuracy whilst also allowing some flexibility for Service Providers in terms of device specification and cost.
3. All standards should be generic such that Service Providers can procure the best value device recorders available, subject to minimum standards,
4. Measurement tolerances applied should not be device specific. Hence, a Service Provider that installs a lower accuracy device will not receive a bigger tolerance.
5. Feed in of existing infrastructure / measurement device standards should be allowed wherever feasible. For example, if we are happy to rely on data from sources currently for certain Services as much as possible we will look to continue to do so.

Full details of the overall measurement device standards required are set to be published in advance of the next round of procurement, due end of November. These standards have been developed based on the technology classes which have entered into the trials. The TSOs acknowledge that in the future some of these standards may well be considered overly onerous for certain technology providers such as small scale or residential DSM providers. As a result, these standards may be assessed or updated from time to time based on feedback and learnings built up over time and as new technologies become proven for System Services.

At a high level the proposed measurement standards will require a measurement device to be installed at each individual component providing a Service. For the case of a hybrid this will require measurement of each component of the hybrid for System Services. For DSM, this requires the installation of a measurement device at every IDS, unless otherwise agreed with the TSOs on a case by case basis. These devices should be accurate within the following standards on resolution, accuracy and storage:

Data Resolution

The TSOs proposes the following as Minimum Data Resolution requirements:

Service	Minimum Data Resolution (MDR)	Minimum Time Synchronisation Accuracy (% of MDR)
DRR	20ms	10%
FPFAPR	20ms	10%
FFR	Contracted Rise Time / 5 (400ms for 2 second response time)	10%
POR	1s	10%
SOR	1s	10%
TOR1	1s	10%
TOR2	1s	10%

Table 4: Minimum Sampling and Time Synchronisation Resolution Accuracy

The minimum standards set out in Table 4 effectively require sampling of at least 5 samples by the minimum horizon window for FFR and POR. For SOR and TOR1, the 1 second resolution has been retained as it aligns with real-time SCADA (Supervisory Control and Data Acquisition) data provided by most providers currently and is not seen as a major burden for Service Providers to adhere to.

For FPFAPR and DRR, the 20ms sampling times are effectively half of the minimum response time for DRR. This decision was taken in the context that it was proposed that performance monitoring of these Services should not be done on a monthly basis. Rather, significant breaches of compliance would be monitored from time to time. In this context 20ms sampling should be adequate to show a unit has responded approximately in line with an expected response.

The accuracy of the time synchronisation of measurement devices becomes more stringent as Service durations get shorter. In effect, this standard will likely result in provision of Services such as POR and SOR to be accurate within timeframes likely to be achievable via Network Time Protocol (NTP) methods whereas the faster acting Services such as FPFAPR and DRR will likely require Global Positioning System (GPS) time synchronisation techniques. The provision of FFR may be achievable by NTP; however, GPS synchronisation may be required in some cases, particularly where the enhanced product scalar for sub 2 second response times are considered.

Data Inputs and Accuracy

Measurement devices should be capable of operating within the measurement ranges and accuracies expressed in Table 5, where “n” denotes the nominal operating point of measurement device installation.

Data Input	Measurement Range	Accuracy (% of Nominal "$_n$")	Applicable to
Frequency	45-55 Hz	0.02	FFR,POR,SOR,TOR1
3 Phase Active Power	0 – 5 P_n	1	All
3 Phase Reactive Power	0 – 5 Q_n	1	FPFAPR, DRR
Individual Phase (R-S-T) Voltage Readings	0 – 1.5 V_n	0.2	FPFAPR, DRR
Individual Phase (R-S-T) Current Readings	0 –5 I_n	0.5	FPFAPR, DRR

Table 5: Measurement Device Range and Accuracy Standards

Data Capture and Storage Requirements

For each Service the measurement devices must be capable of triggering, capturing and storing data within the timeframes specified in Table 6. The measurement devices must be capable of triggering for this duration in line with the data resolution requirements described previously.

Service	Pre – Trigger Time	Post – Trigger Time	Trigger Type
DRR	5s	55s	Voltage – Under (on any phase)
FPFAPR	5s	55s	Voltage – Under (on any phase)
SIR	NA	NA	NA
FFR	60s	20s	Frequency - Under
POR	60s	15s	Frequency – Under
SOR	60s	90s	Frequency – Under
TOR1	60s	300s	Frequency – Under

Table 6: Data Triggering Specifications

2. Verification of Third Party Data Provision Techniques

Traditionally, the TSOs have owned and operated all measurement equipment which has been used for payments and performance monitoring of providing units. However, in the future it is anticipated that Service Providers will be required to install their own device recorders and provide this data to the TSOs. Given this, the question of verifying the accuracy of this data needs to be considered. This section looks at possible approaches to doing this.

Use of System Frequency Data

One possible approach to the verification of this data is to carry out a comparison of time stamped frequency data provided by the Service Provider against frequency data owned by the TSOs. Frequency across the power system can effectively be considered as one single value. In reality, the system frequency can deviate slightly in different parts of the grid. However, these deviations are generally relatively small.

The most accurate readings of system frequency available to the TSOs currently are taken from Phasor Measurement Units (PMU). There are a number of these devices currently installed across the network. All these devices are GPS time stamped which generally can produce accuracies to within 1uS. As part of the trials, an assessment was carried out of how trialist's frequency data correlated with data recorded from PMUs.

Given that minor differences in frequency can occur on the power system in different regions, it was important to assess if the TSOs owned measurement device readings differ significantly, in particular during events. This phenomenon is most likely to occur during quick changes in system frequency on networks with large load centres and with weak electrical strength between them.

To assess this, PMU readings were taken from four geographically dispersed sources across the network, during times of all under frequency events, throughout the trials. Comparisons were made across the four devices to see what was the largest difference recorded across the four PMUs for each time stamp. This data was recorded over a 10 minute period before and after the event to see what the average differences seen were. This was then reassessed over the window of +/- 10 seconds and +/- 1 second of the nadir occurring.

A "Best Average System Frequency" reading was then taken as the average frequency reading across the four PMUs. This was used to compare against data provided by Service Providers during the trials. Two parameters were used to carry out this assessment:

a) The recorded frequency nadir (Hz); and

b) The recorded frequency nadir time (seconds).

From assessment of the results it became apparent that the time synchronization mechanisms applied by certain devices did not provide accurate response times with some devices showing differences of up to 57 minutes. This demonstrates clearly that the method of time synchronization used by the providers is either faulty or does not meet the required standard. The best shown adherences to nadir time recordings were less than 100 ms. The magnitude of the nadirs recorded were generally quite accurate (within 0.02 Hz in most cases).

This analysis has shown that third party data can contain errors. The use of a "Best Average System Frequency" approach to verifying the accuracy of this data offers the TSOs a mechanism to independently verify accuracy of frequency measurements and time synchronization.

Use of Less Granular Streamed Data

Although the TSOs may not have measurement equipment at a high enough accuracy to measure fast acting services, there are less granular data sources available. This data is provided in real-time and can provide details on providing units operating positions such as their active power output. Interpolation of this data can be used to assess over a number of events if there are significant differences between what is provided by the Service Provider post event.

Installation of Measurement Devices at selected locations

Although the TSOs may not have measurement equipment at a high enough accuracy to measure fast acting services, there are less granular data sources available. This data is provided in real-time and can provide details on providing units operating positions such as their active power output. Interpolation of this data can be used to assess over a number of events if there are significant differences between what is provided by the Service Provider post event.

Audit / Witnessing

The TSOs may elect to witness, review and sign off on device recorders as part of a compliance testing process. Within this, the TSOs may elect to return to the test site to review the measurement device, ensuring it remains within its cabinet and there doesn't appear to be any signs of tampering with the device.

3. Application to Aggregators and Hybrids

Hybrids

For Hybrids, it is proposed that a measurement device is installed on each of the individual sub-providing units connected behind the connection point, as well as an additional recorder at the connection point. This is to ensure the output produced by each component equates to what is actually exported onto the system.

Where a hybrid unit cannot disaggregate between its sub providing units, the best method to measure will be assessed on a case by case basis.

Aggregators

For the purpose of measuring the performance of aggregators, the TSOs do not have access to one second data on an IDS level to be able to verify signals received. Hence, different approaches have to be considered in relation verification of DSU data.

Each DSU is expected to provide an aggregated availability and megawatt response signal in real-time at a 1 second resolution. Firstly, the aggregate response signal will be used to cross reference high speed data sent to the TSOs post event as a cross reference.

In addition to this, the TSOs have also requested the installation of a signal that effectively aggregates the load readings at the main incomer of all IDS'. In providing this it effectively allows the TSOs to do two things:

1. During an event, how much this signal drops by can be used as independent verification of the calculated megawatt response signal provided.
2. Over longer durations (e.g. 30 day average) this signal can be cumulated up and compared against energy meter readings as an independent verification.

Overall, a number of approaches to ensuring accuracy of third party data have been assessed during the trials. These offer the TSOs a mechanism to independently verify the data received. If certain Service Providers appear to be consistently flagged over sustained periods of time when running these checks, then it is proposed that there should be some mechanism contained within the compliance requirements of Service Provider's contracts which allow the TSOs to discount payments where they believe tampering or incorrect data is being provided.

Trial Format and Learnings

As part of the 2017 overall learnings, trialists were asked to provide feedback on the format and structure used. This feedback along with the TSOs learnings will help to shape the format and design of future trials.

Overall, trialists fully supported the purpose of the qualifier trials and believed they achieved their overall objectives. However, there were a number of common themes which it was suggested either could be done differently, or perhaps may no longer be appropriate for future trials. These are discussed below:

1. Procurement and Selection Process

From the TSOs perspective the running an industry consultation and full procurement process tool took significant time and resources to deliver. Overall, the proposed format of the trial did not change significantly and some lots within the procurement received no industry submissions. From trialist's perspective, the time taken to run these aspects ate into the trial commencement date significantly.

Additionally, given the timing between the procurement process and start of the trials it was necessary to require as part of the procurement process that any tenderer would need to be connected and operational in advance of the trial commencing. This effectively excluded any technology which is not currently connected and operational on the system in time for the trials to start.

2. Trial Start Up

The time between end of procurement, production and signing of contracts to commencement of trials last year effectively took place over the space of one month. This timeline was extremely challenging for all involved and effectively meant that where trialists did not already have the following it was unlikely they would have this in advance of commencing the trials;

- Real-time signals and controls,
- Measurement Equipment installed and operational, and
- Compliance Testing completed and signed off.

Over the trials, a number of providers had significant issues with providing these over the early months.

From the TSOs perspective, this short lead time into the trials left little time to fully understand the operating setup of each participant, develop detailed project plans and agree key milestones and learnings to be achieved.

3. Trial Format

The format of running fifteen trials in parallel over a pre-defined time had merit last year in the fact it allowed the TSOs to attempt to prove as many of the larger technology classes in advance of the next procurement process as possible. However, in terms of the running of the trials themselves and the learnings that can be obtained such large numbers of trials in a short period was very challenging. Given the move towards six monthly procurement refreshes going forward in the main procurement process this need to ensure trialists are qualified in advance of a window is no longer as important.

It is the opinion of the TSOs that each trial should have its own format, timelines, learnings to be achieved and agreed project plan and that these should be based on the contents and complexity of each trial. Where possible future trials should run as an end to end approach where required signals, testing processes and measurement devices and defined and installed in advance of the trials commencement.

Future Selection Process Considerations

The TSOs are currently looking at the feedback and learnings achieved for this year and how these feed into future selection processes. It is anticipated that many of the technologies currently on the system at scale will be proven for System Services following the outcomes of this trial. As such the TSOs envisage future trial processes may become more and more bespoke and distributed. As a result the following at a high level may be considered for future trials;

1. Greater interactions and coordination with the DSO / DNO as majority of trialists are likely to be connected at distribution level.

2. Provenability trials should continue but are open to all System Services. The TSOs should weigh the value of different Services more heavily dependent on their value to the system.

3. Measurability trials may be amended to become Compliance and Standards Trials. These trials will be open to trialists whose technology classes are proven but wish to demonstrate novel approaches to current compliance and standards. This could consist of any of the following;
    a. New approaches to measurement of aggregators.
    b. New mechanisms for provision of signals.
    c. Technologies providing Services in an inherently different approach.

4. The trial selection criteria should be defined and remain for a number of years to allow units not currently operational the opportunity to partake in future trials.

5. In cases where historical data may already be available to prove a technology class then this should be used as much as possible to identify provenability rather than running bespoke trials.

In future we should run fewer trials resulting in less overlaps of milestones with other ongoing trials.

Conclusions and Next Steps

Overall, the DS3 Qualification Trials 2016 – 2017 achieved the two core objectives set out.

It is a finding of the 2017 QTP that all technologies participating in the POR and FFR trials should be considered as proven technologies for these Services going forward.

It is a finding of the 2017 QTP that all technologies participating in the DRR and FPFAPR trials should not yet be considered as proven for the provision of these Services.

Table 7 shows in detail the findings of this report with respect to provenability.

Technology Class / Sub Class	Services Applicable
Wind - Wind Farm Control	FFR, POR, SOR,TOR1
Wind – Emulated Inertia	FFR,POR
Demand Side Management (DSM)	FFR,POR,SOR,TOR1
Synchronous Compensator and Flywheel Hybrid	FFR, POR,SOR,TOR1
Centrally Dispatched Generating Unit (CDGU)	FFR
HVDC Interconnectors	FFR

Table 7: Technologies that can considered as Proven Technologies

Classification as a "Proven" technology will allow a Service Provider to submit a tender into the next Central Procurement Process for provision of System Services. However, it does not guarantee a Service Provider will receive a contract. This will be decided based on the contents of the tenderer's technical submission. Part of this submission will assess the tenderer's ability to adhere to minimum standards relating to testing, compliance and signals installed, much of which has been identified as requirements throughout this trial process. Therefore, although a technology class may be considered proven there may be specific work to be undertaken by individual tenderers in order to be successful in future tender processes.

Twenty-six key findings and learnings from the trials are documented throughout the report.

In respect to the FPFAPR and DRR trials, although Wind and CDGUs could not be considered proven for the provision of the Services as an outcome of these trials, the TSOs propose that alternative approaches will be undertaken to further understand the provision of DRR and FPFAPR in order to determine how various technologies can be deemed proven for these Services in advance of the Central Procurement Process. This will likely be based on the evaluation of historical fault record data gathered by the TSOs.

The next steps following the trials will include:

1. Capturing the learnings from the trial and inputting them into DS3 System Services Procurement and Contractual arrangements for future procurement processes.

2. The design of the Qualification Trials for 2018 will commence based on the learnings and feedback obtained from 2017.

Following the completion of the Qualification Trials for 2017, the TSOs have identified twenty six findings. These findings will inform the TSOs' decisions relating to System Services product design, procurement and contractual arrangements, and other TSO systems and processes.

Table 8 summarises the findings of this report.

#	Name	Details
1	Application of the Product Scalar for the Faster Provision of FFR	Consideration should be given to only applying the Product Scalar for the Faster Provision of FFR to units that can provide 90% of their maximum recorded provision identified during the testing process over the FFR timeframe. The overall volume contracted for FFR in such cases would remain based over the minimum provision identified during testing over the FFR window (2 to 10 seconds). In respect to aggregators of Services, the same principle would apply based on the aggregate response of the DSU as a whole achieving within 90%.
2	Performance assessment of FFR by CDGUs to cover the entire window but weight the initial response more heavily	The use of a snapshot in the performance monitoring of the provision of FFR by CDGUs may not be a reliable metric. Consideration should be given to applying a time-weighted averaging of data samples over the entire horizon window, weighting the earlier time samples in the 2 to 5 second time frame more heavily.
3	Calculation and application of an Available Active Power Error Factor for WFPS units	Consideration should be given to calculating an error factor for WFPS units providing reserve Services. This error factor would feed into assumptions of when the unit is available to provide the Services and the performance monitoring of the Services. It is suggested that this error factor could be calculated based on absolute 95th Percentile Error recorded for each WFPS unit multiplied by the Percentage Skew times 2.

		AAP Error Factor = 95th Percentile Error (MW) x $\frac{\text{Skew (\%)}}{100}$ x 2 The error factor would be calculated quarterly based on the most up to date information available to the TSOs. Skew (%) refers to, on average, how often the error is biased such that AAP is greater than AMW.
4	Calculation and application of a Wind Resource Variance Factor	To account for potential short term variances in availability, it may be appropriate that a WFPS should only be considered available to provide FFR, POR and SOR when its calculated headroom is greater than 5% of the unit's Registered Capacity. For TOR1 this value would be increased to 10% to account for the longer time frame.
5	Considerations for the performance monitoring of Wind Farm Control responses	The performance monitoring of WFC responses to a reserve event should consider taking account of variances that may occur in Available Active Power during an event by: • Applying tolerances also applied to assumptions on availability; • Reducing the pre-event time to between 2 to 10 seconds; • Accounting for wind decrease in the expected response at times when the AAP drops off below associated tolerances.
6	Availability Forecasts from Variable Technologies as a component of Performance Scalar	The TSOs should consider that variable technology types be required to forecast their availability of Service provision at least four hours ahead of real-time to allow the TSOs to schedule Service availability accurately in real-time. Service Providers would be allowed some lead time to adapt to these requirements. To incentivise this, the DS3 System Service Performance Scalar could focus on two components in future: • Scaling Element based on a unit's response to system events (PE), and • Scaling Element based on a unit's availability forecasting accuracy (P_A).

		The overall DS3 Performance Scalar would then be calculated as: **DS3 System Services Performance Scalar = PE x PA** Specifics of how each forecast would be evaluated and what would need to be provided by Service Providers would be specific to each technology class.
7	Considerations for the assessment of WFC availability forecasts	Consideration should be given to evaluating WFC forecasting accuracy on a cumulative basis, by summing the errors over all trading periods when the Available Active Power exceeds 20% of the unit's Registered Capacity.
8	Impact assessment of Grid Code interactions	It is a finding of the 2017 QTP that an impact assessment of interactions between requirements for Service provision under Grid Code and DS3 System Services may be beneficial in order to identify conflicts and recommend appropriate actions if any arise.
9	WFPS providers of EI to only contract for WFC up to same horizon window	It is a finding of the 2017 QTP that consideration should be given to WFPS providers of Emulated Inertia not being permitted to contract for WFC for subsequent horizon windows; this is due to the fact that a response provided through Emulated Inertia effectively results in a unit entering a recovery mode.
10	Application of separate product scalars to the provision of EI and WFC by WFPS units	Consideration should be given to the application of separate System Service product scalars to providing units that deliver a Service using two mutually exclusive mechanisms combined i.e. Emulated Inertia and WFC. Each separate product scalar would account for that component of the providing unit's capabilities.
11	EI to be considered proven for FFR and POR time horizons	Consideration should be given to wind farms providing Emulated Inertia being eligible to contract for both FFR and POR. However, this would be contingent on their compliance test demonstrating a response for the entire horizon window of POR.

12	Considerations for the assessment of EI availability forecasts	It is a finding of the 2017 QTP that the evaluation of the accuracy of the forecasting of Emulated Inertia from wind could be based on the imposition of AAP forecasts on to reserve curve parameters and an assessment of the unit operating in this region in real-time.
13	New signals to manage Service provision from new technologies being a minimum requirement to receive a contract	It is a finding of the 2017 QTP that consideration should be given to mandating that the installation of new signals to manage System Service provision be part of the minimum compliance standards within DS3 System Service contractual arrangements. Specifics of the additional signals required for each Service Provider would depend on their technology class / sub-class and the Services they wish to provide. High level descriptions of what new signals may be required for each new technology class are described within each technology's section of this report.
14	New providers of System Services to have completed a compliance test in order to get a contract for System Services	It is a finding of QTP 2017 that consideration should be given to classifying certain energy-limited devices as static providers of operating reserve Services. This would apply to units that cannot sustain dynamic provision of Service and also cannot control their recharge. Energy-limited devices that must recharge their resource immediately following their response can cause a reduction in the overall volume of Services available in further horizon windows, as these devices will be recharging during these times.
15	Classification of energy-limited devices without control of their recharging as static providers	It is a finding of QTP 2017 that consideration should be given to classifying certain energy-limited devices as static providers of operating reserve Services. This would apply to units that cannot sustain dynamic provision of Service and also cannot control their recharge. Energy-limited devices that must recharge their resource immediately following their response can cause a reduction in the overall volume of Services available in further horizon windows, as these devices will be recharging during these times.

16	Considerations for the performance monitoring of EI	Consideration should be given to focusing the performance monitoring of Emulated Inertia on the ability to sustain the Service over the entire horizon and recharge window. Additionally, the pre-event output would be calculated closer to the time of the event due to the variability of the resource providing it.
17	Consideration of the classification of DSM units as static, stepped static or dynamic providers	It may be appropriate to consider further differentiating the various capabilities of demand side units in the provision of reserve System Services into static, stepped static and dynamic, with a dynamic response more valuable than a static response.
18	Considerations for the assessment of DSM availability forecasts	It is a finding of this report that the evaluation of a DSU's forecast of reserve availability account for whether the DSU is providing the Service(s) or has been dispatched in the Energy Market. As a result, it would be proposed to only assess reserve forecasting for the period when the associated DSU has not been dispatched in the Energy Market. In addition, both the evaluation of a pass/fail based on a trading period or based on a cumulative error approach would be suitable for the performance monitoring of DSM.
19	Consideration for the establishment of processes to approve provision of Services from distribution-connected units	Consideration should be given to the establishment of a clear and transparent process for the approval of distribution-connected System Service Providers. Where possible, this process would give as much certainty to the DSU as possible in terms of forecasting their likely congestion going forward, even if this required the process to be more restrictive.
20	Consideration that an IDS can only be contracted with 1 DSU for provision of both System Services and Energy	It is a finding of this report that it may be appropriate that an Individual Demand Site could only be contracted with a single DSU operator to provide both System Services and operate in the Energy Market. Further consideration may need to be given as to whether this represented a barrier to entry to either market.

21	Consideration that DSUs should have flexibility to distribute their portfolio of IDSs across System Services and Energy	Consideration should be given to the principle that a DSU be able to provide System Services and Energy Services from different portfolios of IDSs should they wish to do so. However, the TSO would require visibility of the interactions between these Services and as a result this may limit this flexibility to some extent.
22	Expansion of the Operational Certification process for DSM units	Consideration should be given to the expansion of the existing TSO Operational Certification process to capture certification of System Services from all DSM providers.
23	Interactions of provision of reserve or ramping Services not to impact on a provider's ability to deliver SIR	It is a finding of QTP 2017 that if the provision of another System Service impacts on the ability of a provider to deliver SIR, then the unit may only be considered available for one of these Services.
24	Incentivisation of Higher Sensitivity Droops Only to be Applied to Units with Sub 1-second Response Times	It is a finding of QTP 2017 that units that are unable to deliver the FFR Service faster than 1 second may not be incentivised to provide higher sensitivity droops in response to frequency events.
25	Consideration of the use of a time delay factor in the performance monitoring of fast-acting devices	It is a finding of QTP 2017 that the use of a time delay factor in the performance monitoring of frequency controlled Services be considered for fast acting devices, or those with higher sensitivity droop equivalents.
26	Consideration that Performance Scalars not apply to the provision of FPFAPR and DRR	It is a finding of this report that a performance scaling element may not be appropriate for the FPFAPR and DRR Services, but that the Services could be assessed from time to time in line with the compliance requirements of the contract.

Table 8: Summary of Findings