DS3 System Services

Qualification Trials Process Outcomes and Learnings 2017

06 November 2017

Disclaimer

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.

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

Provenability			Measurability		
DS3 System Service[2]	Technology Category[1]	Number of Trialists	**DS3 System Service[2]**	Technology Category[1]	Number of Trialists
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

The trials ran for 6 months with two core objectives:

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 trialling; 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 below provides a graphical flow representation of these trial objectives.

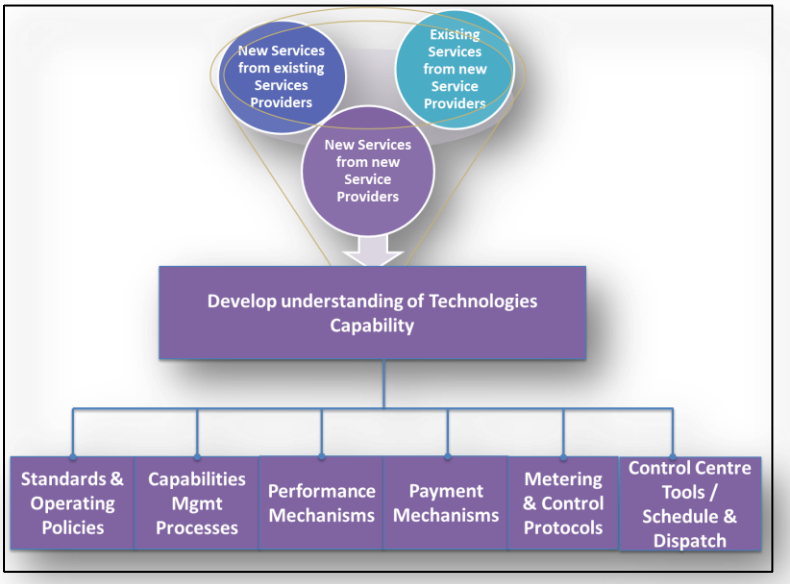

Figure 1: Graphical Representation of DS3 Qualification Trial Objectives

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 2 provides an overview of the technologies that should be considered to be proven for particular System Services arising from the 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. 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.

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

Technology Class / Sub Class[1]	Services Applicable[2]
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[3]	FFR, POR,SOR,TOR1
Centrally Dispatched Generating Unit (CDGU)	FFR
HVDC Interconnectors	FFR

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. The findings themselves are summarised below.

[1] Explanation of Acronyms and technology classes can be found in Table 5 of this report.

[2] Explanations of these Acronyms can be found in Table 3 and Table 4 of this report.

[3] As this trial is of a hybrid combination of technologies, some of the learnings and findings identified may only be applicable to this specific unit and setup.

Table 3: Summary of Findings

#	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 (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.

#	Name	Details
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 (P_E), 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 Service Performance Scalar = P_E X P_A 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.

#	Name	Details
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.

#	Name	Details
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 implementing 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.
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.

#	Name	Details
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.

#	Name	Details
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.

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Background

1.1. EirGrid and SONI

EirGrid and SONI are the Transmission System Operators (TSOs) in Ireland and Northern Ireland. It is our job to manage the electricity supply and the flow of power from producers to consumers. Electricity is generated from gas, coal, peat and renewable sources (such as wind, Solar PV and hydro power) at sites across the island. Our high voltage transmission network then transports electricity to high demand centres, such as cities, towns and industrial sites.

We have a responsibility to enable increased levels of renewable energy to generate on the power system while continuing to ensure that the system operates securely and efficiently. In 2010, we published the results of the *"Facilitation of Renewables"* studies. Those studies identified a metric called *"System Non-Synchronous Penetration"* (SNSP) as a useful proxy for the capability to operate the power system safely, securely and efficiently with high levels of renewable generation. SNSP is a real-time measure of the percentage of generation that comes from non-synchronous[4] sources, such as wind generation, relative to the system demand.

The studies identified 50% as the maximum level of non-synchronous renewable generation allowable on the power system until solutions could be found to the various technical challenges identified. If this limit had not been increased, curtailment on installed wind could have risen to over 25% per annum.

1.2. The DS3 Programme

Our 'Delivering a Secure Sustainable Electricity System (DS3)' programme sought to address the challenges of increasing the allowable SNSP up to 75% by 2020 where by the curtailment of wind would be reduced to approximately 5% per annum.

DS3 incorporates mutually reinforcing innovative technical, engineering, economic and regulatory initiatives. It is divided into three pillars:

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[4] Non-synchronous generators supply power to the electrical grid via power electronics. Power electronics are used to adjust the speed and frequency of the generated energy (typically associated with wind energy) to match the speed and frequency of the transmission network.

1. System Performance
2. System Policies
3. System Tools

DS3 is not only making the necessary operational changes to manage more renewable generation, it is also about the evolution of the wider electricity industry and implementing changes that benefit the end consumer. From the onset, the integration of wind generation presented a range of challenges previously unseen in the power sector. Through collaboration with the Regulatory Authorities and the wider electricity industry, DS3 has developed a number of innovative and progressive solutions.

The results of the programme are now beginning to deliver benefits to the consumer with the allowable SNSP level now increased to 60% and a trial of 65% currently ongoing. It is expected that similar trials will be conducted in the coming years with a view to achieving the overall goal of 75% SNSP by 2020 in a controlled manner.

1.3. DS3 System Services

One of the key work streams in the DS3 Programme is System Services. Its aim is to put in place the correct market mechanisms to incentivise adequate levels of system or ancillary service provision to ensure safe and efficient operation of the power system with high levels of non-synchronous renewable generation.

Traditionally, Ancillary Services (or System Services) were contracted in Ireland and Northern Ireland through the Harmonised Ancillary Services (HAS) arrangements. These arrangements consisted of bilateral contracts between the TSOs and the Service Provider and mainly consisted of large conventional Centrally Dispatchable Generating Units (CDGUs). Under the HAS arrangements, 7 of the 14 System Services were contracted for with 7 'New' services being introduced through the System Services arrangements. These new Services account for new system scarcities, which occur when operating the system with high levels of non-synchronous generation. Of these 7 new services, four went live as part of the Interim Arrangements in October 2016 with 3 remaining services referred to as the 'Fast Acting' services expected to be procured for the first time in 2018.

Table 4 and

Table 5 below give a high level description of the services and how they are categorised.

Table 4: Summary of DS3 System Services Products

Service Name	Acronym	Short Description
Synchronous Inertial Response	SIR	Provision of Inertia from synchronous machines that can operate with low minimum generation point.
Fast Frequency Response	FFR	MW delivered between 2 and 10 seconds in response to automated frequency trigger
Primary Operating Reserve	POR	MW delivered between 5 and 15 seconds in response to automated frequency trigger
Secondary Operating Reserve	SOR	MW delivered between 15 to 90 seconds in response to automated frequency trigger
Tertiary Operating Reserve 1	TOR1	MW delivered between 90 seconds to 5 minutes in response to automated frequency trigger
Tertiary Operating Reserve 2	TOR2	MW delivered between 5 minutes to 20 minutes in response to a control / dispatch instruction
Replacement Reserve – Synchronised	RRS	MW delivered between 20 minutes to 1 hour in response to a control / dispatch instruction
Replacement Reserve – Desynchronised	RRD	MW delivered between 20 minutes to 1 hour in response to a control / dispatch instruction from a zero megawatt starting position.
Ramping Margin 1	RM1	The increased MW output that can be delivered with a good degree of certainty for the given time horizon.
Ramping Margin 3	RM3	
Ramping Margin 8	RM8	
Fast Post Fault Active Power Recovery	FPFAPR	Active power recovery within 250 ms of a voltage fault
Steady State Reactive Power	SSRP	Reactive power response within 40ms of a voltage fault
Dynamic Reactive Response	DRR	MVAr capability during large (>30%) voltage dips

Table 5: Summary of DS3 System Service Categories

Service Acronym	Existing HAS Services	Current System Services	Fast Acting System Services
SIR	No	Yes	No
FFR	No	No	Yes
POR	Yes	Yes	No
SOR	Yes	Yes	No
TOR1	Yes	Yes	No
TOR2	Yes	Yes	No
RRS	Yes*	Yes	No
RRD	Yes*	Yes	No
RM1	No	Yes	No
RM3	No	Yes	No
RM8	No	Yes	No
FPFAPR	No	No	Yes
DRR	No	No	No
SSRP	Yes*	Yes	Yes

*RRS, RRD and SSRP were existing services under the HAS arrangements. However, their technical definitions have been refined under the new DS3 System Services mechanisms.

1.4. Managing the Transition to New Technologies

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.

1.5. The DS3 Qualification Trials Process

A number of technology categories cannot participate in the central System Service arrangements as they are either not deemed to be proven from a Service Provision perspective or they fail to adhere to the current standards and compliance requirements, as outlined within the DS3 System Services Protocol document.

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.

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.

Trial Objectives

The trials ran for six months with two core objectives:

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 trialling; 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 in the executive summary provides a graphical flow representation of these trial objectives.

1.6. 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.

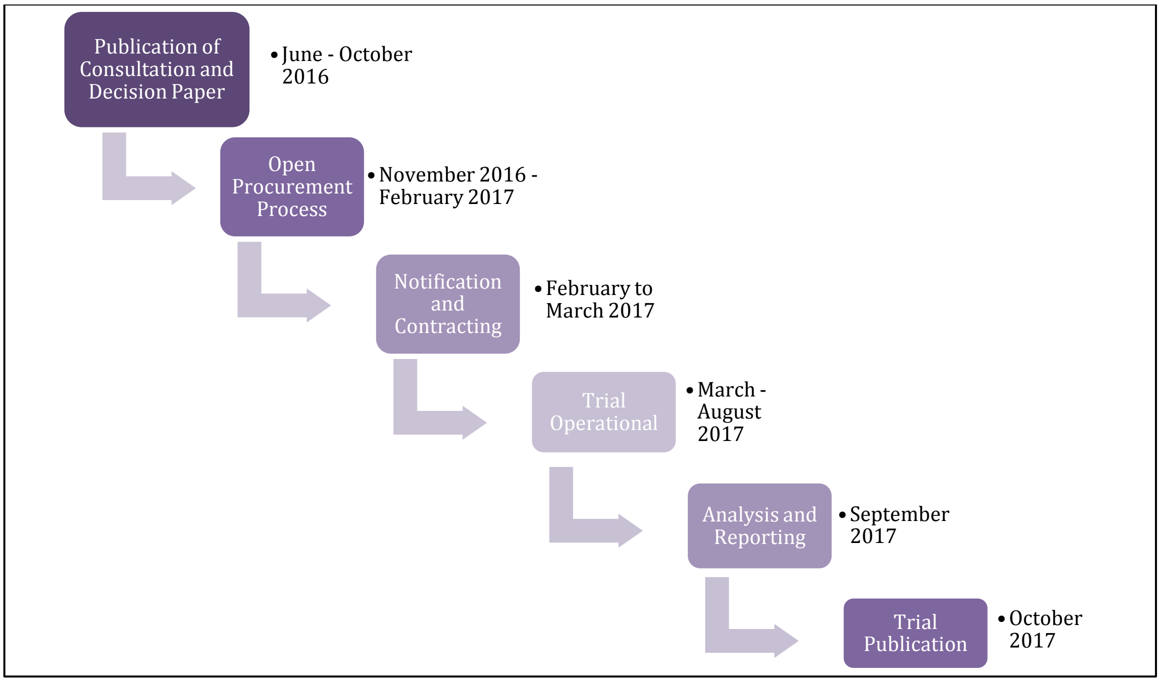

Figure 2: Key Milestones for the 2016-17 DS3 Qualification Trials

Fifteen trials were undertaken in total across a variety of technologies and Services focusing on two themes: ‘provenability’ and ‘measurability’. The provenability trials covered the proving of new technology classes to provide existing services whilst the measurability trials focused on the proving of a number of technology classes, new and existing, to provide the three new fast acting Services with a particular emphasis on how to measure these Services. Inherently, there were overlaps across the learnings achieved between each trial and the format of this paper attempts to acknowledge that by combining the trials into eight categories.

Table 6: List of 2016/17 DS3 Qualification Trials and categories

Provenability			Measurability		
DS3 System Service	Technology Category	Number of Trialists	**DS3 System Service**	Technology Category	Number of Trialists
POR	Wind using Farm Controller response (WFC)	2	**FFR**	Centrally Dispatched Generating Unit (CDGU)	1
POR	Wind using Emulated Inertia (EI)	3	**FFR**	Wind -EI	1
POR	Demand Side Management (DSM)	2	**FFR**	DSM	1
POR	Hybrid of Synchronous Compensator and Flywheel /Energy Storage Unit (ESU)	1	**FFR**	High Voltage Direct Current Interconnector (HVDC IC)	2
			FPFAPR/DRR	CDGU	1
			FPFAPR/DRR	Wind	1

1.7. Structure of the Report

This paper will be cover two key areas, provenability and measurability.

The provenability section will cover each trial each trial category under each of the following areas;

- Background,
- Provision of Service, and
- Operational Complexities and Findings.

The measurability section details the standards and requirements for third party measurement devices, focusing on the fast acting services as well as approaches which could be utilised by the TSOs as mechanisms to independently verify whether the data provided adheres to these standards.

The final section of the report provides discussion and feedback on the format and structure of the trials ran in 2016 – 2017 for feed in to future trial processes.

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,
- Provision of Service,
- 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.

The Provenability section has grouped the trials into the eight categories shown in

Table 7.

Table 7: Provenability Trial Categories

#	Technology Class	Trials Applicable
1	CDGU	FFR
2	Wind (WFC)	FFR / POR
3	Wind (EI)	FFR / POR
4	DSM	FFR / POR
5	Synchronous Compensator and Flywheel (ESU)	POR
6	IC	FFR
7	CDGU	FPFAPR / DRR
8	Wind	FPFAPR / DRR

Trial Events

During the trial period, the system frequency dropped below 49.8 Hertz (Hz) on fifteen occasions (one of these was caused as a result of a voltage fault on the network and subsequently discounted from further analysis). These events are used to gather data on the reserve services trials relating to FFR and POR. A summary of the dates and frequency nadirs of these under-frequency events are shown in

Table 8 below. Depending on the operating setup of each Service Provider at the time, some Service Providers may only have been expected to respond to a subset of these events. Of the fourteen events, only two events had nadirs below 49.5 Hz, the current trigger for assessment of a unit's performance to an event.

Table 8: Summary of Underfrequency Events recorded during the Qualification Trial period

#	Event Date (DD/MM/YY)	Recorded Nadir Time (HH:MM:SS.000)	Recorded Nadir (Hz)
1	21/03/17	12:15:55.300	49.597
2	18/04/17	23:43:58.300	49.714
3	23/05/17	12:25:19.900	49.687
4	24/05/17	07:32:41.900	49.576
5	08/06/17	00:06:24.500	49.764
6	20/06/17	12:50:44.500	49.387
7	25/06/17	03:51:24.500	49.787
8	28/06/17	05:56:00.300	49.787
9	15/07/17	18:08:55.900	49.384
10	06/08/17	20:18:36.700	49.616
11	06/08/17	23:01:42.195	49.712
12	16/08/17	14:19:59.900	49.787
13	22/08/17	16:15:02.100	49.793
14	22/08/17	20:50:05.000	49.743

Significant local voltage dips in the regions where the trialists providing FPFAPR and DRR were connected did not occur during the trial. As such there is little to no measurable data to assess for these trial categories. Further detail on this will be discussed in the sections on each of these trial categories.

CDGU – FFR Trials

Background

The majority of current automatic frequency response System Services (POR, SOR and TOR1) procured on the system today is from CDGU type units such as Combined Cycle Gas Turbines (CCGT). Therefore, the main purpose of this trial category was to better understand whether CDGUs can effectively provide this type of service within the 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 as part of the Qualification Trials as detailed below.

Table 9: Operational Characteristics of CDGUs throughout trials

Unit	Droop %	Trigger-point
Unit #1	3.4%	49.8 Hz
Unit #2	4%	49.985 Hz

In general, CDGUs can only provide FFR when they are scheduled to do so. This means they must be operational on the system and operating with headroom (a difference between their current power output and maximum possible power output). Whether a CDGU is operating in these regions is dependent on the outcomes of the TSOs' scheduling processes in the energy market. As a result, of the fourteen events which occurred during the trials, the two trialists were only available to respond for a subset of these.

Table 10 gives a summary of events where a response was expected.

Table 10: Summary of CDGUs Expected Responses

#	Unit 1 Response Expected (Y / N)	Comment	Unit 2 Response Expected (Y / N)	Comment
1	N	No headroom	Y	
2	N	No headroom	N	Offline
3	N	Offline	Y	
4	N	Offline	Y	
5	N	No headroom	N	No headroom
6	Y*	No headroom	N	Offline
7	N	No headroom	N	Offline
8	N	No headroom	N	Offline
9	Y*	No headroom	N	Offline
10	N	No headroom	N	Offline
11	N	No headroom	N	Offline
12	N	No headroom	N	Offline
13	N	No headroom	N	No headroom
14	N	Offline	N	No headroom

Provision of Service

This section looks in more detail at the responses provided during the CDGU trials in line with what the units were expected to provide. Expected responses were calculated based on the lesser of:

- The unit's contracted FFR value;
- The unit's declared FFR value; and
- The unit's idealised Governor Droop demanded output based on the change in frequency from a pre-determined point.

Contracted values and declarations were based on estimates agreed pre-trial with Service Providers based on our experience of provision of other reserve services. No specific test was undertaken in advance of the trials to verify exact quantities for these values.

Provision of the FFR Service for each event was considered under two areas of focus:

1. The trialist's initial response.

   This was 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.

Tables shown below are categorised based on whether the achieved response was within certain tolerances of the unit's theoretically expected response using colour coding as follows:

- Less than 70% and greater than 1 MW deficit is Red;
- Between 70% and 90% and greater than 1 MW deficit is Orange;
- Greater than 90% or less than 1 MW deficit is green.

Response One

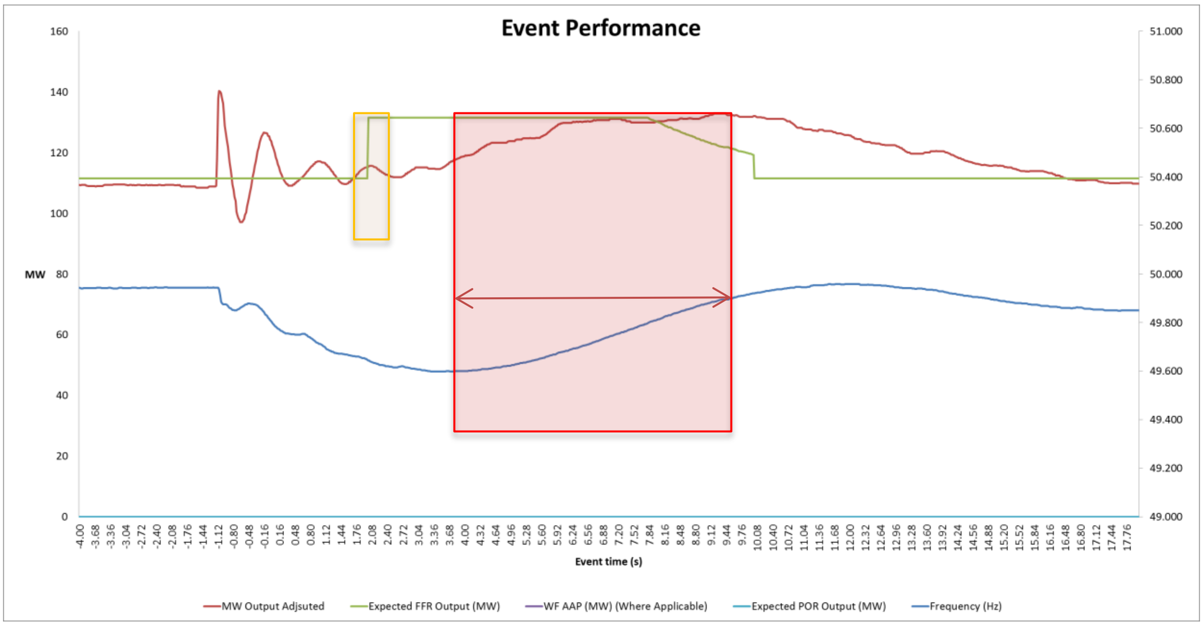

Figure 3: Response of Unit 2 to Event 1 - 21/03/2017

Table 11: Summary of response values for Unit 2 to Event 1 - 21/03/2017

	Expected (MW)	Achieved (MW)	∆%	∆MW
FFR Initial	20	3.93	**19.65%**	**16.07**
FFR Average	18.14	13.66	**75.3%**	**4.48**

The results show a slow response by the unit. At the start of the FFR horizon taken, the unit's output has increased by less than 20% of what it was expected to achieve. In addition, this is taken at the crest of a ripple in power output, making its response at this point appear more significant than it actually was. This can be seen graphically within the orange box within the graph.

Over the remainder of the FFR event time frame the unit's response does pick up, showing a rise up to and even exceeding the expected response by about the eight second mark. On average, over the entire event horizon, the unit achieved roughly 75% of its expected response.

Some learnings from this event are:

1. **Governor detection and slow response time delays**

   A significant time delay is seen between the system frequency actually falling and the unit responding. From reviewing the graph, ignoring initial inertial swings, the time between the event initialisation and the unit governor picking up and sustaining active power response appears to be in the region of three seconds.

   In addition, when comparing the time between the frequency nadir occurring and the unit achieving its maximum active power response, the time difference between these two appears to be in the region of six seconds, as shown in the red box above. The main driver of this difference is the time the unit takes to adjust its output to a change in frequency. In the case of CDGUs, as the units are generally much heavier thermal plant, their ability to ramp over short time frames such as the two seconds associated with FFR is much more difficult to achieve.

2. **Impacts of Inertia on the response of CDGUs**

   Synchronous Generators provide uncontrolled Synchronous Inertia to the system inherently, which is remunerated through the SIR Service. This can be seen clearly in the response of the unit initially as the unit oscillates in response to the sudden drop in system frequency. These swings appear to be most prevalent at times of frequency ripples (high changes in the rate of change of frequency).

These 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.

Responses Two and Three

Responses shown to events 2 and 3 below appear to show similar issues as Response One. However, the significance of the time-delays and inertial swings appear less apparent in these events. The reasoning for this is believed to be that the frequency appears to have a much smoother decline towards the nadir in both cases.

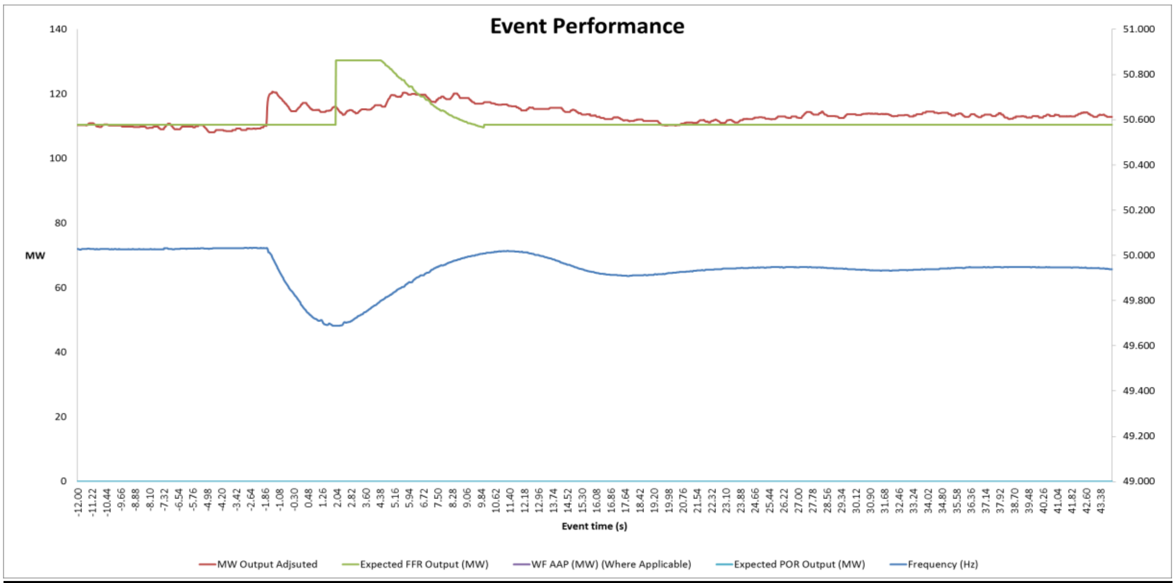

Figure 4: Response to Unit 2 to Event on 23/05/2017

Table 12: Associated summary of response values

	Expected (MW)	Achieved (MW)	Δ%	ΔMW
FFR Initial	20	5.47	**27.35%**	**14.53**
FFR Average	11.3	7.17	**63.5%%**	**4.13**

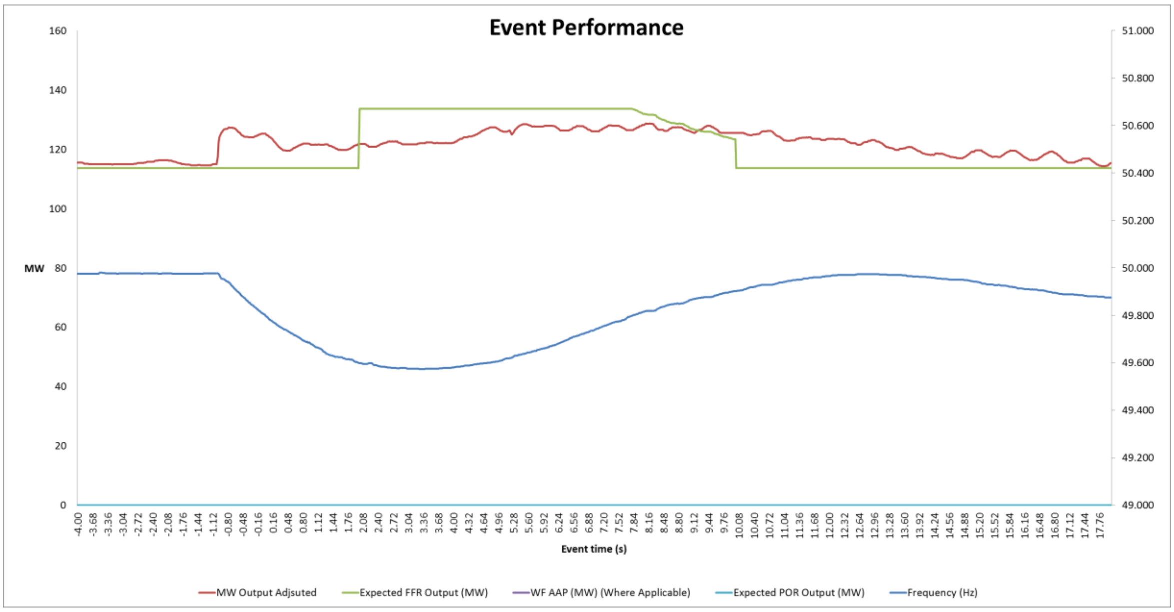

Figure 5: Response to Unit 2 to Event on 24/05/2017

Table 13: Associated table of response values

	Expected (MW)	Achieved (MW)	∆%	∆MW
FFR Initial	20	8.07	**40.35%**	**11.93**
FFR Average	18.47	11.85	**64%**	**6.62**

None of the responses shown in the trials demonstrated responses within the tolerances considered green over the trial period. Further consideration was given to whether this was due to the specific unit's assumed contractual parameters or would it likely be consistent with industry more generally.

To investigate this further some Phasor Measurement Unit (PMU) data was pulled for a number of other CDGUs that would have been contracted to provide POR during events through the trial. Figure 6 below shows an example of one of these CDGU's response to a system event during the trials. An assumption that the unit would contract for 40% of its current POR contracted volume was made for assessing performance.

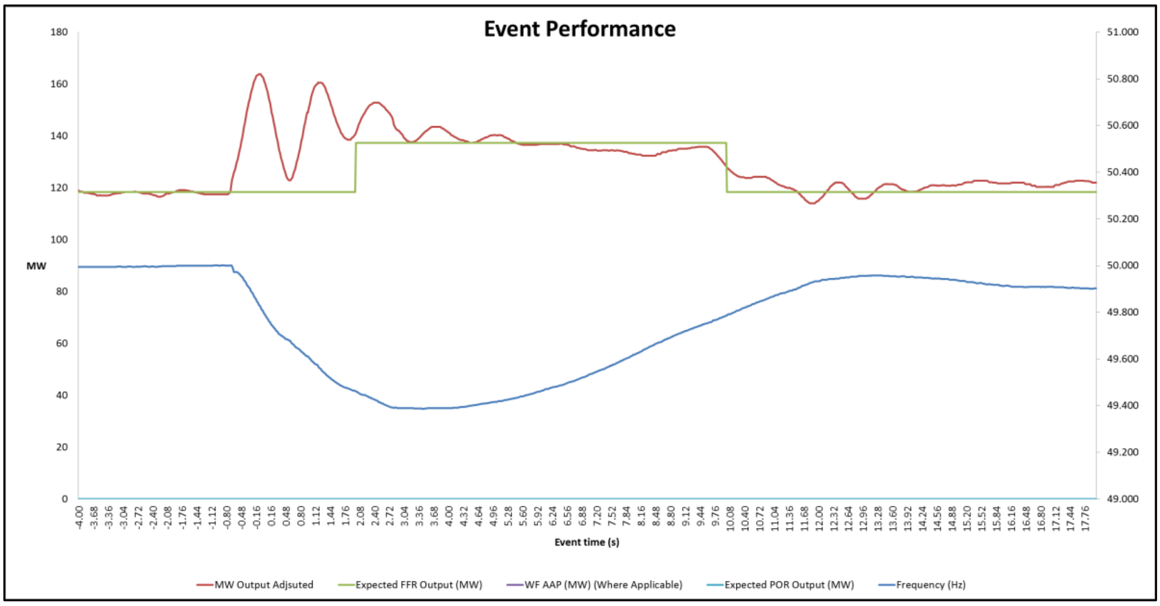

Figure 6: Response of Additional Unit to Event on 15/07/2017

Table 14: Associated table of response values

	Expected (MW)	Achieved (MW)	∆%	∆MW
FFR Initial	19	22.88	**120%**	**+3.88**
FFR Average	19	19.68	**103%**	**+0.68**

From assessing the response of a number of other CDGUs across the FFR timeframes, it is apparent that the responses shown previously do not represent the capability of the technology class as a whole to provide the service but rather an individual unit with a declared value exceeding the plant's true capability. However, learnings taken from the trials in respect of inertia and time delays can once again be seen.

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.

1. Identification and Contracting of sub two second responses

In its decision paper on DS3 System Services Tariffs and Scalars SEM-17-080[5], the SEM Committee approved the introduction of a product scalar for the faster response of

[5] DS3 System Services Tariffs and Scalars SEM Committee Decision SEM-17-080

the FFR Service to incentivise the provision of the Service faster than 2 seconds. However, how this is calculated and interactions between this timeframe and contracted volumes of FFR need to be identified.

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.

An example of this is shown graphically below. Please note the data used in these graphs is purely for illustrative purposes and has not been taken from an actual test results, they are purely for the purpose of illustrating the contents being discussed within this section.

Figure 7 shows an example response of a CDGU to an under frequency step. In this situation the time taken for the unit to detect the frequency and begin to increase its active power response is one second. The time taken to then fully increase its output to an expected level requires a further 4.3 seconds in this case.

In contrast, a device like an Energy Storage Unit (ESU) may be able to detect and respond from its minimum to maximum output in a much quicker manner, well in advance of two seconds. An illustrative example of this is shown in Figure 8.

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.

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https://www.semcommittee.com/sites/semcommittee.com/files/media-files/SEM-17-080%20DS3%20SS%20SEMC%20Decision%20Paper%20Regulated%20Arrangements%20Tariffs%20and%20Scalars%20Final%20version.pdf

3. The exact speed of response of the two second response time is taken as the last sample counting back from two seconds where the unit has retained its response above or in line 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.

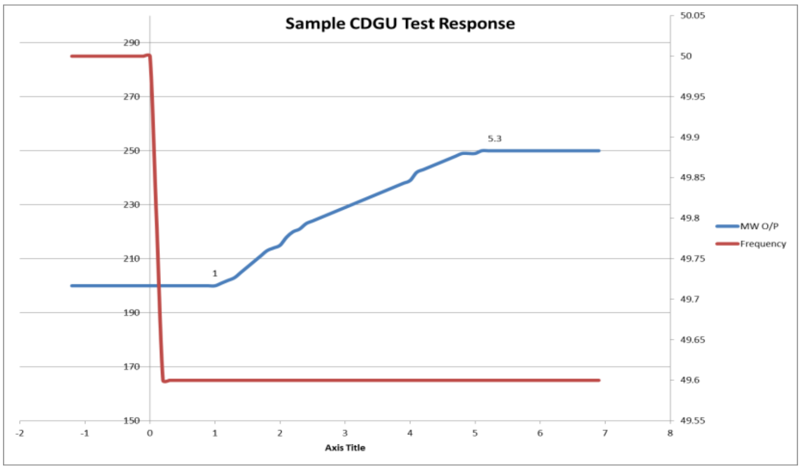

Figure 7: Sample CDGU Response to Frequency Step

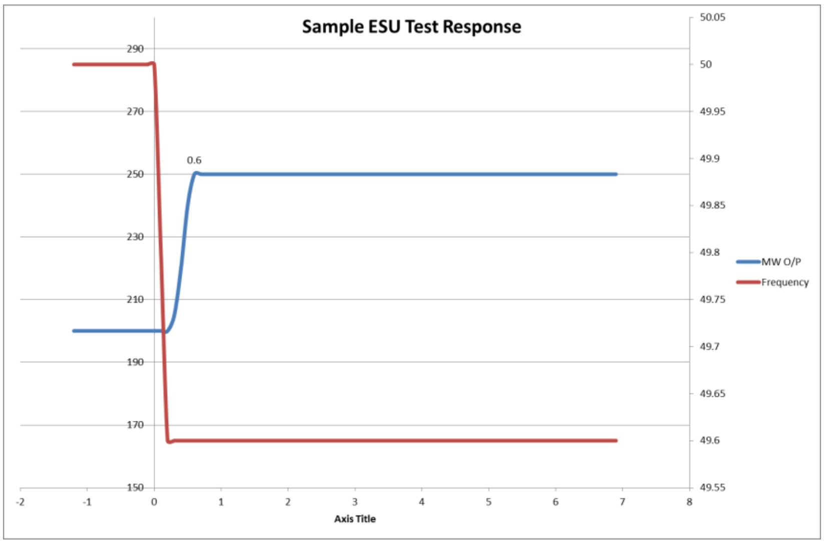

Figure 8: Sample Energy Storage Device Response to Frequency Step

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%.

2. Performance Monitoring of FFR Responses

Learnings 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:

- 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;

- 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;

- However, the responses shown do indicate that CDGUs find it most difficult to achieve response in the early stages of the FFR horizon.

Based on this a number of findings relating to the Performance Monitoring of FFR from CDGUs are described below.

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) currently provide EirGrid and SONI with 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.

WFPS have to provide the following performance under the EirGrid Grid Code:

- A droop response in the range of 2-10% (usually 4%) when the frequency drops below 49.985 Hz, and
- A response which results in at least a 60% increase in output (up to their maximum power available limited by wind resource) within 5 seconds.

These capabilities are tested under the Operational Certification process required to become Grid Code compliant.

For WFPS to provide FFR or POR they must be in frequency response mode and be available. This means:

- For an EirGrid connected WFPS, Frequency Response Status to be enabled (FQR On),
- For a SONI connected WFPS, Emergency Action to be enabled and a percentage Curtailment setpoint issued to the WFPS,
- Additionally, the WFPS must be operating above their Designed Minimum Operating Level (DMOL) and have reduced output to create a difference between output (AMW) and maximum output available (AAP).

The TSOs are incentivised to minimise curtailment on the system and as a result the availability of Wind –WFC to provide FFR and POR during the trials was low.

In total, five WFPS with the required capability to provide frequency response services were contracted through the trials. Only two were specifically trying to prove this mode of the response from this technology class. Both WFPS were set up to provide dynamic responses as detailed in Table 15 below.

Table 15: Operational Characteristics of WFPS -WFCs throughout trials

Unit	Droop %	Trigger-point
Unit #1	4%	49.985 Hz
Unit #2	4%	49.985 Hz

Despite frequency response being enabled for roughly 50% of the trials, there were no times when the frequency trigger point was reached to result in a response. This was due to the fact the difference between the units AAP and AMW was negligible (i.e. the WFPS were not dispatch downed at the times of events).

One event did occur on a WFPS partaking in the Emulated Inertia trials which demonstrated a response to both Wind Farm Control response and Emulated Inertia. This will be explained in the Emulated Inertia trial category.

Provision of Service

Although there were no times when the frequency trigger point was reached to result in a response during the trials, there are other examples which show the capability of WFPS to provide operating reserve using their Wind Farm Controllers.

Test Data Example

WFPS demonstrate frequency response capabilities for POR as part of their current Grid Code Compliance test requirements. Results from these tests show that WFPS can increase output in short time periods. This demonstrates WFPS capability to provide POR and FFR services when available.

Active Power Control Setpoints and Frequency Regulation Example

During the trials, WFPS responded to Active Power Control setpoints and regulated the frequency. Figure 9 and Figure 10 below provide examples. After an active power control setpoint is sent to the WFPS (yellow trace) it increases power output correctly. Figure 10 shows this response happened approximately three seconds after the instruction. System frequency was low between 20:15 and 20:45 on the same day. During this time the WFPS increased its response higher than its Active Power Control setpoint. This is highlighted with a red circle in Figure 9.

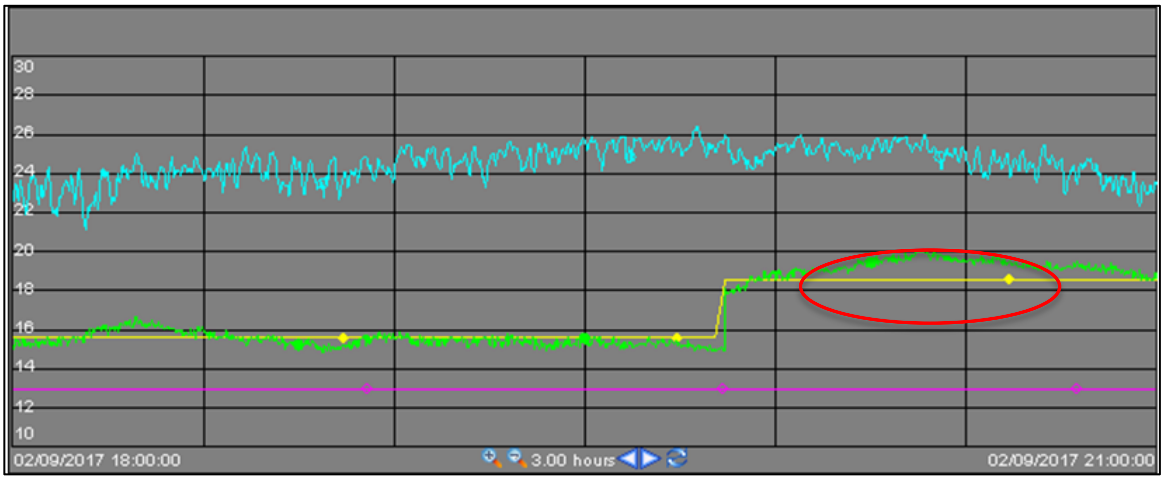

Figure 9: Example of Regulation and Active Power Control from WFPS

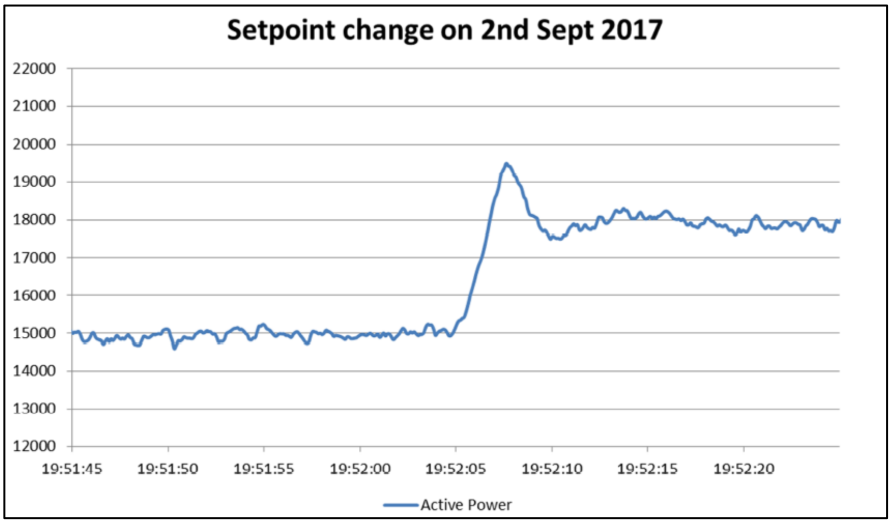

Figure 10: Higher resolution of kilowatt response time at point of Active Power Setpoint issuance

Over frequency Response Example

During the trial period, two high frequency events happened on the system when system frequency was higher than 50.2 Hz. WFPS with frequency response enabled during these times are required to reduce its output.

Figure 11 shows one of the WFPS in the trial response to an over frequency event. The graph shows the WFPS decreases its output 4.3MW with 0.8 seconds of detection. As the WFPS output is close to 0MW (below DMOL) the unit cannot reduce output any further.

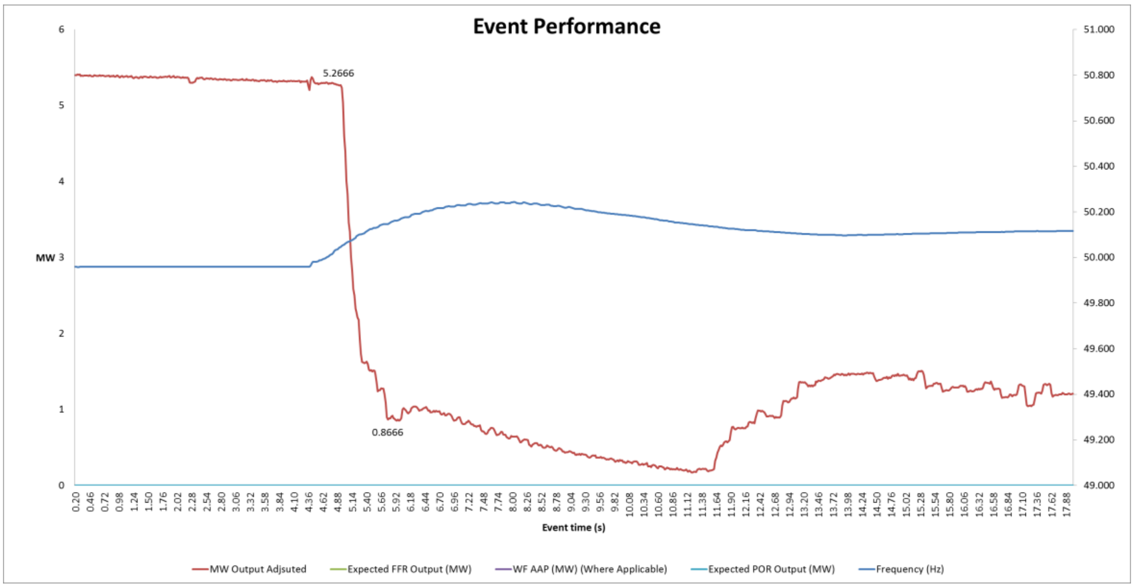

Figure 11: Sample Response of WFPS to over frequency event

Operational Complexities

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

1. **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:

- 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,

- 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.

Analysis of the AAP signals provided by the WFPS in the trials was carried out. The outcome was that across all signals there were data samples with a high absolute error. Over the 6 months of data assessed the most significant errors recorded are shown in Table 16.

Table 16: WFPS Maximum Errors Recorded of AAP Signals during the trials

	1 Minute Data	30 Minute Data
Max Absolute Error (MW)	12.33	12.68
Max Absolute Error (as a % of Registered Capacity (RCAP)	38.36%	8.23%

A probabilistic analysis of the signal errors is shown in Table 17.

Table 17: Additional Error assessments of AAP Signals during the trials

	1 Minute Data	30 Minute Data
Max Average Absolute Error (MW)	0.452	0.307
Associated Variance(MW)	0.263	0.185
Max Average Absolute Error (%RCAP)	1.32%	0.82%
Associated Variance (%RCAP)	0.77%	0.32%
Max 95th Percentile (MW)	1.51	0.98
Max 95th Percentile (%RCAP)	4.4%	2.85%
Max 90th Percentile (MW)	1.12	0.79
Max 90th Percentile (%RCAP)	3.26%	2.13%

At the times the errors occurred assessment was carried out to see how often the error caused the AAP to be higher than AMW output. This showed that the maximum and minimum skews recorded were **92.9%** and **6.57%** respectively. This means that 92% of the time when AAP and AMW output should have been the same, AAP was greater than AMW output. On average across all the WFPS the average skew was between 45%-48%.

Within a relatively high degree of confidence, significant signal error is low, 95 percentile error of 1.51 MW or 4.4% being the most significant. Also the analysis did not show that the error was more likely to be positive or negative.

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.

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

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.

2. 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:

- 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

- The TSOs relying on a service which may not be available in the quantities forecast prior to the event.

Therefore it was important to assess the quantity and probability of wind increase or decrease during events. Assessment in variations of one minute availability data was carried out for all WFPS in the trials over the six month trial period. Table 18 shows the results of the analysis.

Table 18: Variance of Available Active Power experienced over 1 minute horizons

	MW	% RCAP
Max Absolute Change	71.95	91%
Max Average Absolute Change	0.88	1.9%
Associated Variance	1.79	1.14%
Max 95th Percentile	3.49	7.13%
Min 95th Percentile	1.22	4.4%
Max 90th Percentile	2.45	5.26%
Min 90th Percentile	0.9	2.94%

It can be seen that the maximum errors recorded were due to a decrease in wind. However, these values were most likely due to signal failure or the WFPS responding to a local network event. These errors showed 90th percentile errors between 3% to 5% and 95th percentile errors between 5% to 7% of the units registered capacities. The errors as a percentage of registered capacity did not vary significantly depending on the size of each unit.

As the time frame for TOR1 extends to 5 minutes, this analysis was repeated to determine the difference occurring over this longer time frame. Table 19 shows the results of this analysis.

Table 19: Variance of Available Active Power experienced over 5 minutes horizons

	MW	% RCAP
Max Absolute Change	72.33	91%
Max Average Absolute Change	2.13	1.9%
Associated Variance	9.54	3.7%
Max 95th Percentile	7.86	13.39%
Min 95th Percentile	2.29	10.1%
Max 90th Percentile	5.46	9.7%
Min 90th Percentile	1.66	6.9%

The results showed more significant errors between 7% and 10% based on 90th Percentile analysis and between 10% and 13% of the unit's registered capacity.

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.

3. 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:

- 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.
- 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.
- 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.

4. 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.

During the Qualification Trials, WFPS were required to provide forecasts of their expected Available Active Power over different time frames to assess their capability. In general, most trial participants found this difficult. They also experienced difficulty achieving a reasonable level of accuracy. As a result, some participants could only provide forecasts towards the end of the trials, once they developed operational processes to do so.

Two forecast time frames were assessed during these trials:

- A 24 hour ahead forecast was supplied for a 24 hour window (48 Trading Periods in total), and
- A 6 hour ahead forecast for a 6 hour window (12 trading periods in total).

For each trading period (30 minutes) an assumption on the average Available Active Power (AAP) that would be available was provided in MW. This was assessed against actual 30 minute average of AAP seen in real-time. The following data trend analysis was considered:

- Forecast errors as a percentage of units registered capacities,
- Forecast error deviations on longer time horizons,
- Forecast errors as a percentage of the actual AAP experienced,
- Forecast accuracy deviation in Megawatts, and
- Cumulative Errors over entire forecasting horizons (24 hour and 6 hours)

Results of this analysis are presented below.

Table 20: WFPS Forecast Error as a percentage of Registered Capacity

All Percentages shown as a % of RCAP		WF1	WF2	WF3	WF4
6 hours	**Min Absolute Error**	N/A	N/A	0.08%	0.00%
	Max Absolute Error	N/A	N/A	58.01%	49.89%
	Avg. Absolute Error	N/A	N/A	17.06%	8.05%
24 Hours	**Min Absolute Error**	0.41%	0.07%	0.00%	0.06%
	Max Absolute Error	33.60%	49.49%	57.82%	45.81%
	Avg. Absolute Error	10.19%	12.33%	12.42%	11.35%

Table 21: WFPS Forecast Error as percentage of Registered Capacity versus time

All Percentages shown as a % of RCAP	WF1	WF2	WF3	WF4
6-8 hours	NA	NA	13.75%	6.01%
8-10 hours	NA	NA	15.93%	10.03%
10-12 hours	NA	NA	20.62%	8.12%
24-32 hours	9.78%	8.00%	12.42%	10.81%
32-40 hours	9.60%	16.52%	12.41%	12.88%
40-48 hours	11.18%	12.59%	12.42%	10.35%

Table 22: WFPS Forecast Error as percentage of Actual Available Active Power

All Percentages shown as a % of actual AAP		WF1	WF2	WF3	WF4
6 hours	**Min Absolute Error**	NA	NA	0.19%	0.00%
	Max Absolute Error	NA	NA	47316.67 %	49.89 %
	Avg. Absolute Error	NA	NA	2514.84%	8.05%
24 Hours	**Min Absolute Error**	1.72%	0.42%	0.00%	0.15%
	Max Absolute Error	480.83 %	129.51 %	61316.67 %	45.81 %
	Avg. Absolute Error	54.19%	39.90%	1909.98%	11.35 %

Table 23: WFPS Forecast Error in Megawatts (MW)

Megawatt Error		WF1	WF2	WF3	WF4
6 hours	**Min Absolute Error**	NA	NA	0.03	0.00
	Max Absolute Error	NA	NA	19.84	0.50
	Avg. Absolute Error	NA	NA	5.84	0.08
24 Hours	**Min Absolute Error**	0.14	0.05	0.00	0.02
	Max Absolute Error	11.54	39.20	19.78	0.46
	Avg. Absolute Error	3.50	9.77	4.25	0.11

Table 24: Cumulative Error Assessments over forecast horizon window

		WF1 (%)	Culm AAP (MW)	WF 2 (%)	Culm AAP (MW)	WF 3 (%)	Culm AAP (MW)	WF 4 (%)	Culm AAP (MW)	Overall (%)
6 hr	**MIN**	NA	NA	NA	NA	18	377	8	387	**16**
	MAX	NA	NA	NA	NA	100	46	85	36	**98**
	AVG	NA	NA	NA	NA	67	NA	45	NA	**53**
24 hr	**MIN**	42	403	36	1091	24	1206	16	1303	**8**
	MAX	42	403	67	645	98	116	70	576	**100**
	AVG	42	403	48	NA	59	NA	49	NA	**57**

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

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

b) Comparison of error against registered capacity is not an appropriate metric as it inherently results in lower errors during low to moderate wind conditions.

c) Larger forecasting windows produced greater errors, albeit errors over all horizon windows were large.

d) 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.

e) 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.

f) 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 (P_E), 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 = P_E x P_A

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.

5. 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;

a) 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.

b) 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 b) 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.

Unlike WFC response, there is currently no obligation under Grid Code to provide Emulated Inertia. As part of these trials 3 wind farms had the capability of providing Emulated inertia with the 2 of the 3 making the provision of emulated inertia the main focus of their trial.

Given the short duration of service provision (unlikely to exceed the POR timeframes) all the trialists were set up to maximise their responses upon being triggered (provide a static blast). All 3 wind farms expressed uncertainty on the ability to provide the Service at low wind outputs and as such it was assumed where the power output of turbines was below between 20 – 25% of the units Registered Capacities then the units were not expected to respond. Above this amount the WFPS are expected to give a static amount of reserve, in the region of 5% of their registered capacity.

As the service is provided on an individual turbine basis, in many scenarios during the trials the service was only available on a subset of turbines. This was declared in advance of real-time but subsequently resulted in the overall expected values being much smaller in some cases, i.e. a wind farm with 5 MW of Emulated Inertia could only provide 2.5 MW if only half their turbines were enabled at a point in time.

Table 25: Operational Characteristics of WFPS –Emulated Inertia throughout trials

Unit	Droop %	Trigger-point (On)
Unit #1	0%	49.81 Hz
Unit #2	0%	49.81 Hz
Unit #3	0%	49.81 Hz

Provision of Service

Over the duration of the trials a number of events occurred where the Emulated Inertia was expected as detailed in

Table 26 below. Expected responses with an asterisk (*) beside it signifies that the unit was either expected to respond but did not or alternatively not expected to respond but did show a response. In some cases it also signifies the unit was expected to respond but the volume expected was low, as little as 0.167 MW in some cases.

Over the three wind farms there are at least 10 measurable responses recorded from trials. This section of the report will provide commentary on some of the more significant events, which demonstrate learnings on the following key features:

- Response Rise Time
- Response Duration
- Response Recovery
- Response to subsequent events
- Combined response of Emulated Inertia and Wind Farm Control

Table 26: Summary of Expected Responses for WFPS Emulated Inertia Trials

#	Unit 1 Expected Response (Y / N)	Comment	Unit 2 Expected Response (Y / N)	Comment	Unit 3 Expected Response (Y / N)	Comment
1	N	0MW Avail	N	0MW Avail	Y*	Service found to be disabled following investigation
2	N	0MW Avail	N	0MW Avail	N	O/P Low
3	N	O/P Low	N	0MW Avail	N*	O/P Low but provided response
4	N	0 MW O/P	N	0MW Avail	N	O/P Low
5	Y*	Only 0.167 MW Avail	N	0MW Avail	Y	1.47 MW Avail
6	N	0 MW O/P	N	0MW Avail	N	O/P Low
7	Y*	Only 0.167 MW Avail	N	0MW Avail	Y	1.47 MW Avail
8	N	0 MW O/P	N	0MW Avail	N	O/P Low
9	Y	2MW Avail	N	0MW Avail	Y*	1.57 MW Emulated Inertia + Headroom for WFC response.
10	Y	2MW Avail	N	0MW Avail	Y	1.47 MW Avail
11	N	O/P Low	N	0MW Avail	Y	1.47 MW Avail
12	Y*	2MW Avail - did not respond	Y*	Only 0.5 MW Avail	Y	1.47 MW Avail
13	N	0MW O/P	N	O/P Low	Y	1.47 MW Avail
14	N	0MW O/P	N	O/P Low	Y*	O/P Low but provided response

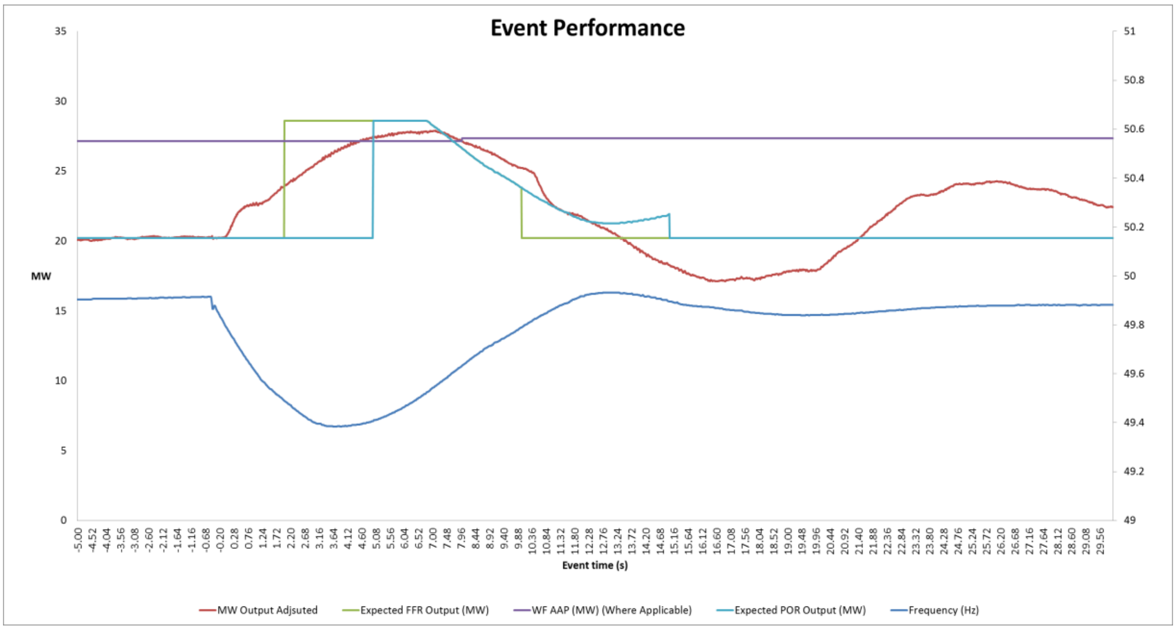

Figure 12: Response of Unit 3 to Event 13

Table 27: Associated Summary response of Unit 3 to Event 13

	Expected Response (MW)	Achieved Response (MW)	Δ%	ΔMW
FFR Initial	8.4	3.7	**44%**	**4.7**
FFR Average	7.4	6.4	**86%**	**1**
POR Initial	8.4	7.2	**86%**	**1.2**
POR Average	4.2	4.0	**95%**	**0.2**

Figure 12 shows one of the key responses seen during the Emulated Inertia trials. This graph shows a combined response of both Wind Farm Control and Emulated Inertia. As such, it also demonstrated proof of WFC response. From review of the graph the following can be found:

1. Wind can provide both Emulated Inertia and Wind Farm Control responses up to the point at which Emulated Inertia is being provided.

2. The Wind Farm control response appears somewhat slow within the initial 2 seconds for FFR provision, with the majority of response in this time coming from emulated inertia.

3. At approximately 12 seconds following the event the unit ceases providing Emulated Inertia as the frequency has recovered above a pre-defined threshold

(49.86 Hz in the case of this trial). As a result, the Emulated Inertia provision enters into a recovery mode.

4. Overall the unit has responded reasonably well in line with its expected response achieving 85% and 95% of its FFR and POR expected values on average

5. Following this the unit fails to respond in line with the expected response as the unit has entered a recovery period. Determination of whether the unit's recovery in the ten to twenty second windows exceeds the increase provided in the FFR time horizon is difficult to display given the unit has also provided WFC response during the FFR timeframe which increases the overall provision seen in this horizon.

6. Responses provided by non-synchronous technologies such as wind are not prone to inertial spikes such as is seen with synchronous technologies. As such, whether they responded in line with their expected responses should be much clearer to determine from results.

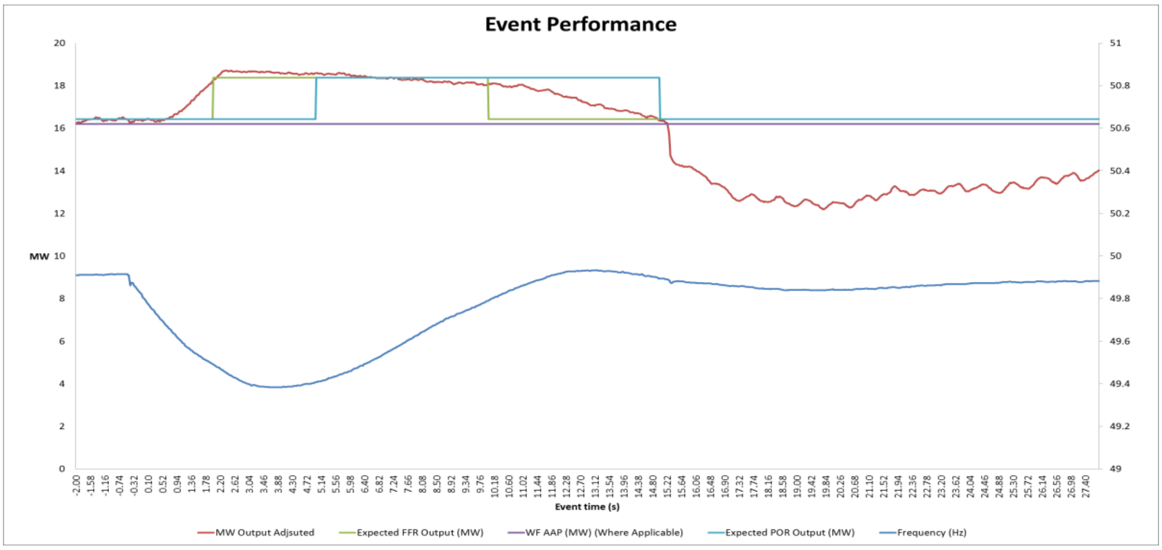

Figure 13: Response of Unit #1 to Event 10

Figure 13 and Figure 14 show responses of Emulated Inertia events where the frequency dropped below the trigger point and remained below this point for a sustained period. This demonstrated the ability of the trialists to maintain their responses for the entire duration of services. Both units retain their response for greater than 90% of what they are expected to provide for the duration of the FFR service but appear to drop off towards the end of the POR horizon window sustaining responses for approximately 12 and 12.6 seconds respectively. During the remainder of the trials no further events occurred which tested this capability. In line with current test procedures, service providers are contracted for the minimum volume they provide over an entire service horizon window, demonstrated through a capability test. As such, although the wind farms in question didn't display responses for the entire fifteen seconds required for POR, they did demonstrate enough to indicate that, with minor modifications to control system logic, the technology as a whole could be capable of sustaining responses in excess of fifteen seconds. Those who could not would be captured through assessment during compliance testing.

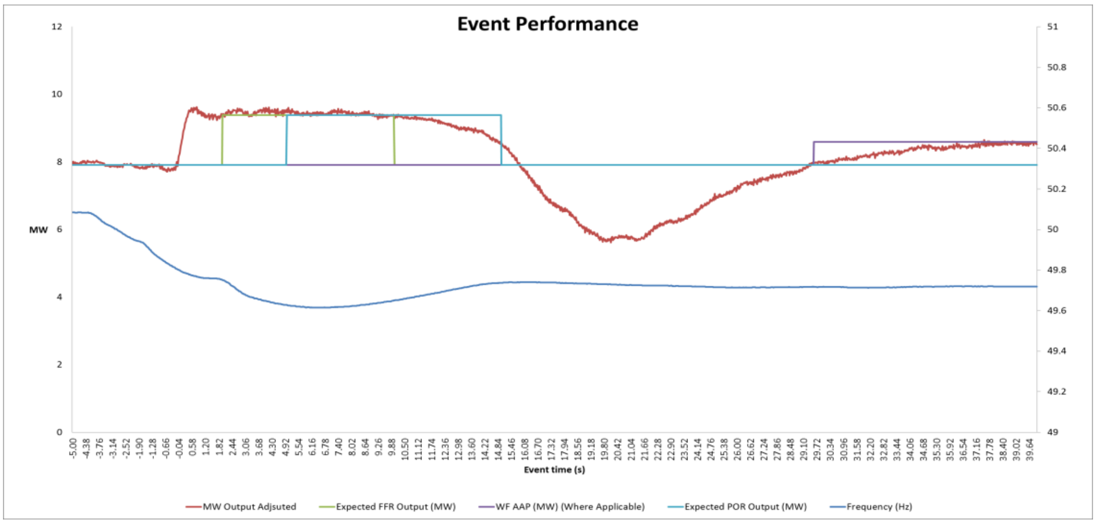

Figure 14: Response of Unit #3 to Event 10

Under the definition of FFR there is a requirement that a unit cannot absorb energy in the ten to twenty second time horizon than it put in during the FFR response window (zero to ten seconds effectively). From assessment of responses seen during the trials 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 is dependent on the power output at the time of the event.

Separately, one trial participant has provided details on a new software upgrade to their service provision control design which effectively allows them to control the speed at which they recover energy. This would result in them controlling their recovery speed such that they ensure they remain within the recovery requirements for FFR.

Operational Complexities

1. Interactions between WFC and EI Response

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 Schedule 9 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.

2. 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.

3. 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 15 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.

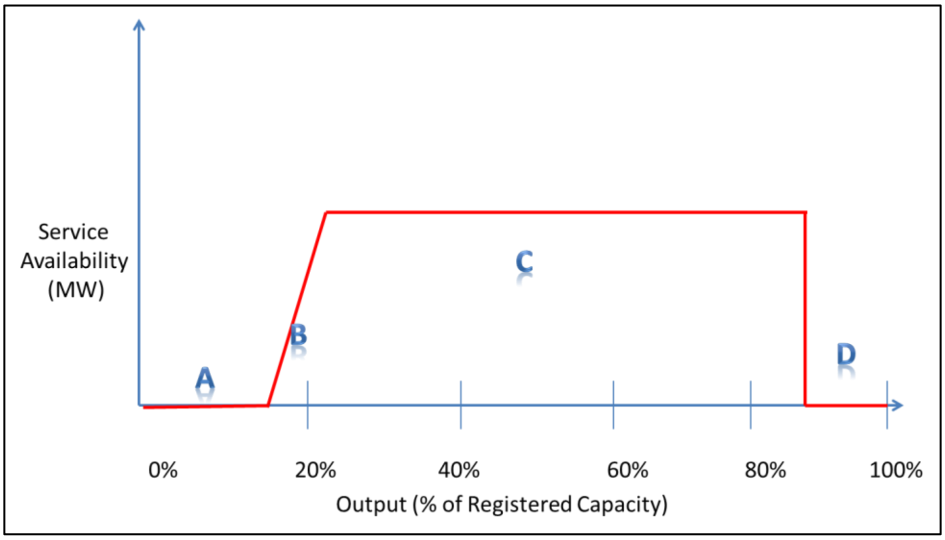

Figure 15: Example of a WFPS Emulated Inertia Reserve Curve

> **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.

4. 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:

a. On /Off Control – The ability for the TSOs to enable / disable the service.

b. 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.

5. 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 15 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.

6. 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.

7. 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;

a) 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.

b) 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.

c) 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.

d) 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.

e) 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;

a) The need for certainty of response, and

b) 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.

Specifics of both DSUs' operating characteristics can be found in Table 28. Both trial participants had indicated the capability to provide response durations for either discrete periods of time, until the frequency recovered or a combination of both. During these trials, both trialists were setup to respond for fixed periods of time.

Table 28: Overview of DSU Operating Parameters during the trials

Parameter	DSU #1	DSU #2
Type	Stepped-Static	Static
$F_{Trigger}$	49.8 Hz	Ranged between 49.8 - 49.6 Hz
$F_{TriggerRange}$	0.5 Hz	0
Droop	1%	NA
T_{MinON}	90	300

Provision of Service

A number of events occurred where the DSUs were expected to respond as detailed in

Table 29 below. The main reasons DSUs were not expected to respond to some events during the trials was due to their trigger points not being breached or some sites were unavailable in the early stage of trial setup.

Table 29: Summary of Expected Responses for DSMs

#	DSU 1 Expected Response (Y/N)	Comment	DSU 2 Expected Response (Y/N)	Comment
1	N	Not Avail	Y	
2	N	Not Avail	N	Not triggered
3	Y		N	Not triggered
4	Y		Y	
5	Y		N	Not triggered
6	Y		Y	
7	Y		N	Not triggered
8	Y		N	Not triggered
9	Y		Y	
10	Y		Y	
11	Y		Y	
12	Y		Y	
13	Y		Y	
14	Y		Y	

Sufficient responses were seen across the DSM trials generally, shown graphically below with one showing a completely static response and the other a stepped static response.

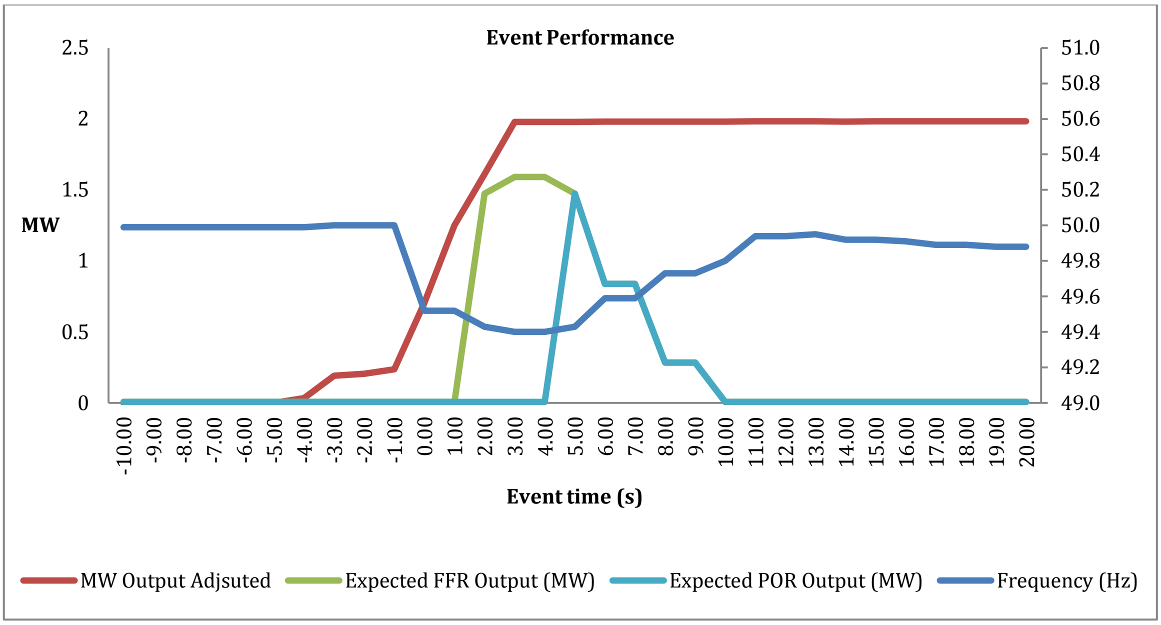

Figure 16: Response of Unit 1 to DSM proportional FFR and POR for Event 6

Table 30: Table of Response values of Unit 1 to DSM proportional FFR and POR for Event 6

	Expected (MW)	Achieved (MW)	Δ%	ΔMW
FFR Initial	1.47	1.60	109%	0.14
FFR Average	0.92	1.93	209%	1.01
POR Initial	1.47	1.98	135%	0.51
POR Average	0.33	1.97	589%	1.64

Figure 16 shows a proportional expected response to the frequency event. From reviewing the response a number of things are evident:

- The unit can respond within and in advance of the two second response times required under FFR,
- The unit responds in excess of its required response,
- The unit shows the static response to time whereby it remains responsive from 90 seconds post event trigger,
- The pre-event timeframe selected can have significant impacts on the level of response recorded as the load before the event tends to change frequently, and

- Following an event response, the load available for response is lower than pre event. This is due to the fact certain sites will return load post event in much slower rates than others.

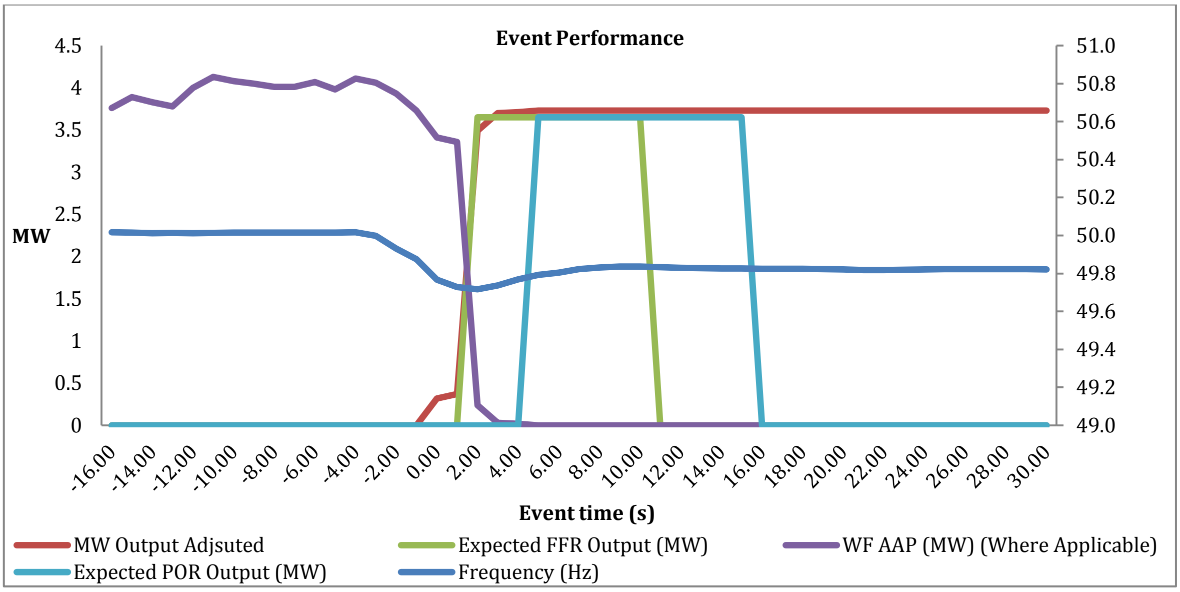

Figure 17: Response of Unit 2 to Static FFR and POR reserve response for Event 10

Table 31: Summary Table of Unit 2 response to Static FFR and POR Event 10

	Expected (MW)	Achieved (MW)	Δ%	ΔMW
FFR Initial	3.64	3.49	96%	0.15
FFR Average	3.64	3.70	101%	0.05
POR Initial	3.64	3.73	102%	0.09
POR Average	3.64	3.73	102%	0.09

Figure 17 shows a static response to a frequency event. During this response the unit clearly demonstrated that:

- The unit responds in excess of its required response, and
- The unit can respond within the 2 second response times required under FFR

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.

1. **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.

Table 32: DSM Parameters and Descriptions

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.

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. The three categories are:

1. Full Dynamic,
2. Stepped Static, and
3. Basic Static.

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 28.
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.

In this simple example, the trigger point of each IDS is dynamically shifted to ensure the overall DSU can provide a dynamic type response. Each IDS is limited such that once it responds for greater than 5 minutes it will cease responding, after which time it will be marked as unavailable for at least 60 seconds. The unit is attempting to track the system frequency as it moves from 50 Hz. In each time period, the overall required response is different and different IDS' are triggered constantly to continue to provide this service. Sites being unavailable are then updated in the overall availability of the service remaining.

Table 33: Illustrative Example of DSM Dynamic Response (IDS Technical Limitations)

Name	Reduction Available (MW)	T Max On (s)	T Min_Interval (s)
IDS1	0.5	300	60
IDS2	0.4	300	60
IDS3	1	300	60
IDS4	0.6	300	60
IDS5	1	300	60

Table 34: Illustrative Example of DSM Dynamic Response (Response Triggering Sequence)

Time (s)	Frequency (Hz)	Expected	IDS1	IDS2	IDS3	IDS4	IDS5	Net Response Provided (MW)	Remaining Availability (MW)
0-60	50	0	Off	Off	Off	Off	Off	0	3.5
60-120	49.9	1	Off	Off	On	Off	Off	1	2.5
120-180	49.9	1	Off	ON	N/A	On	Off	1	1.5
180-240	49.95	0.5	On	N/A	Off	N/A	Off	0.5	2
240-300	49.9	1	N/A	Off	Off	Off	On	1	2

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:

a) The DSU must contain greater than one discrete step.
b) The DSU must have frequency measurement and direct control of each IDS contracted.
c) The DSU must be capable of providing the Global $F_{Trigger\ On}$ and the Global $F_{Trigger\ Range}$ parameters.
d) The Global $F_{Trigger\ Range}$ must be adjustable over a range up to 2 Hz (4% Droop)
e) The DSU must then either be able to respond to recovery due to either Time or Frequency.

f) If responding to frequency the $F_{Trigger\ Off}$ should be at least the same as $F_{Trigger\ On}$
g) If responding to time then the Global $T_{Min\ On}$ should be at least equivalent to the service the DSU is applying for.
h) 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 28 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.

2. 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.

3. New Signals Required for DSM Reserve Provision

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

a. 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.

b. 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).

c. 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.

d. 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.

4. 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.

5. 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.

A number of workshops have taken place between the TSOs and DNO/ DSO to date to develop processes for managing this approval process given the considerations above.

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:

- 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),
- 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,
- 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.

6. 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.

7. 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. This is graphed at a high level below.

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.

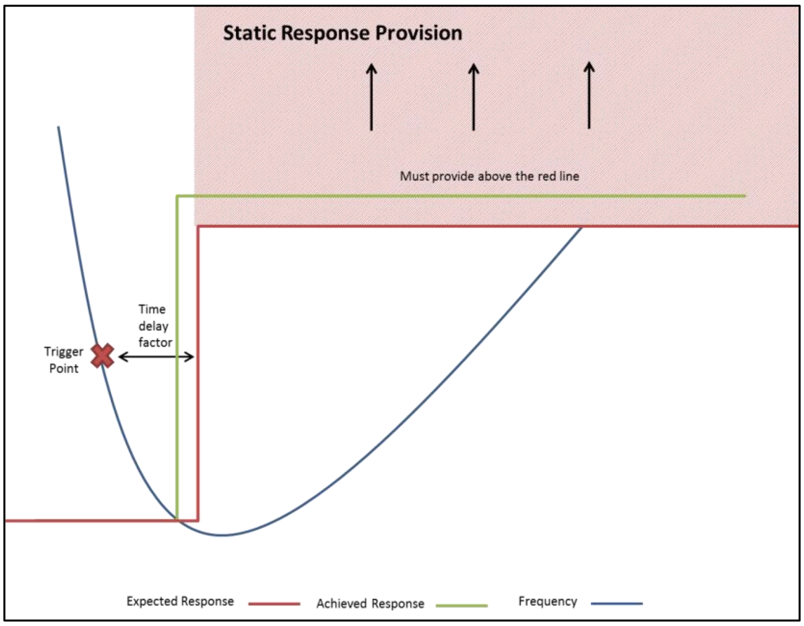

Figure 18: Proposed approach to Performance Monitoring of DSM Static Response

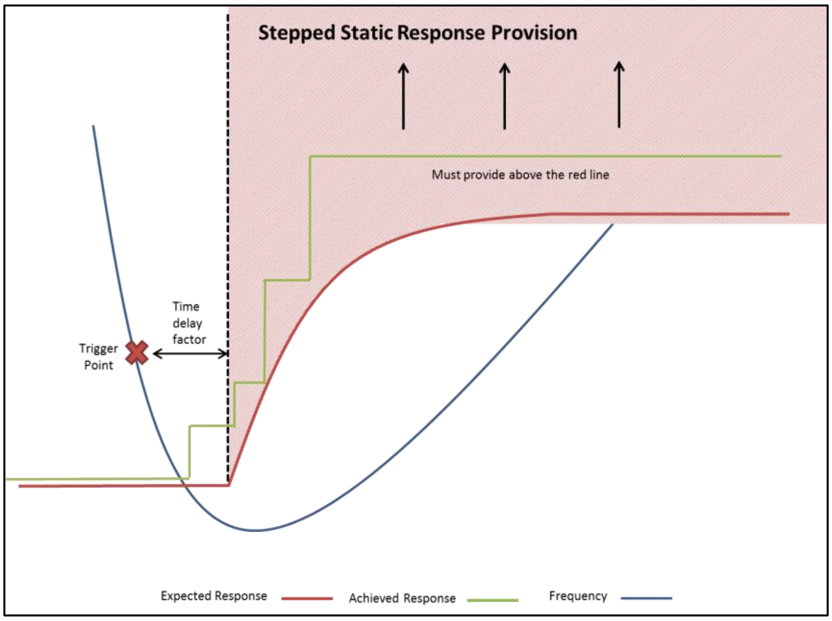

Figure 19: Proposed approach to Performance Monitoring of DSM Stepped Static Response

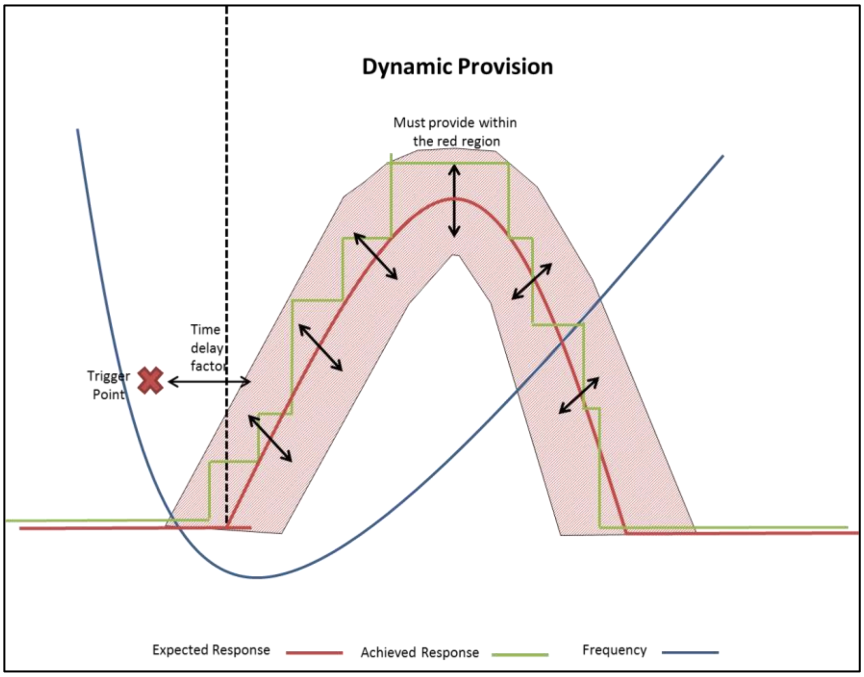

Figure 20: Proposed approach to Performance Monitoring of DSM Dynamic Response

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

Background

The synchronous compensator trial was run under the hybrid technology trials in combination with a WFPS. Both technologies are connected behind a single connection point. However, the WFPS and synchronous compensator were electrically separated and hence the assessment of each component of the trialist's technology could be undertaken in isolation. 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.

The operational settings of the Synchronous Compensator partaking in the trials are detailed in

Table 35 below.

Table 35: Details of Operating Parameters of Synchronous Compensator Unit

Parameter	Value
Trigger On Frequency	49.8 Hz
Megawatt O/P Expected	0.85 (0.95 MW increase)
Max Discharge Duration Expected	14.5 seconds
Response Type	Static

Provision of Service

Over the course of the trials the Synchronous Compensator provided a response to four separate events. These events showed a strong correlation with the theoretical expected response of the unit. Following a number of responses with response times in the region of 6 seconds the controller was tuned to provide responses faster to demonstrate FFR provision.

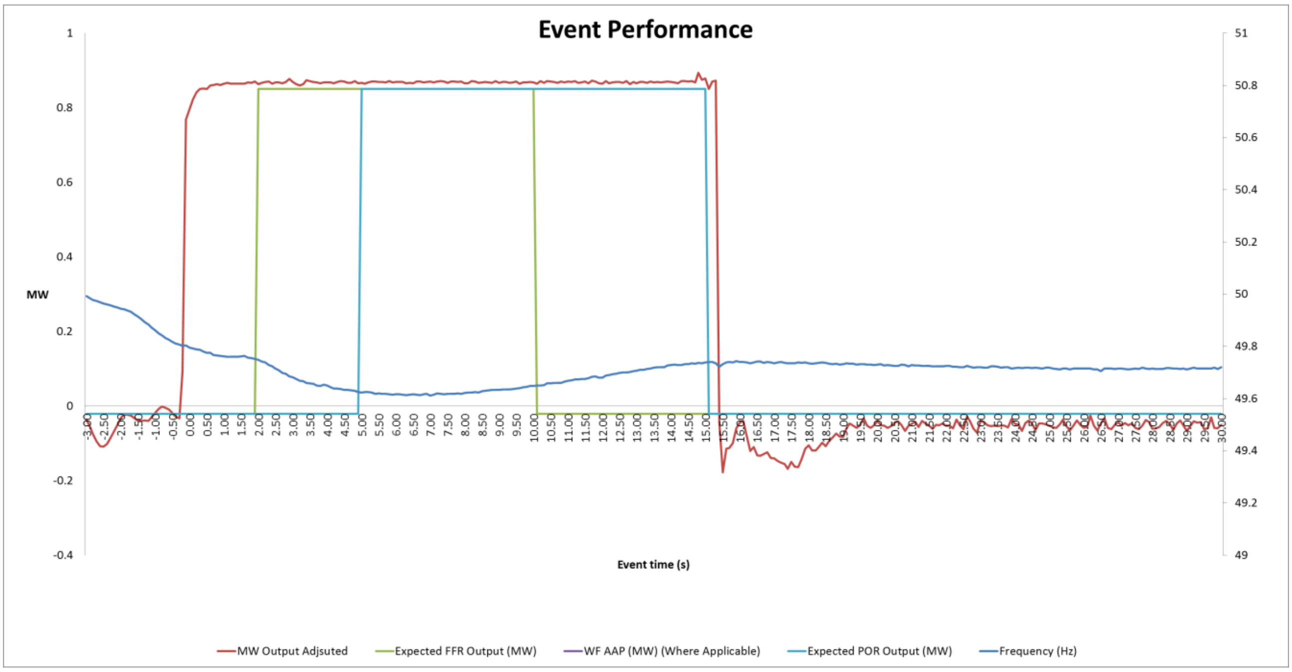

Figure 21: Response of Synchronous Compensator to Event 10

From assessment of Figure 21 the following can be determined:

- The unit provided a response time well in advance of 2 seconds (~0.5 seconds),
- The unit sustained its response over the entire FFR and POR duration before fully discharging as expected,

- The expected response and achieved responses were almost identical across the entire event (within 2% across all four metrics),
- Following a complete discharge of the synchronous compensator it appears to recover a small amount of energy immediately following its response. This has also been prevalent across other responses provided. It is believed however that this can be alleviated through tuning of the controller and therefore is not indicative of the technology class more generally.

Operational Complexities

1. **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 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.

2. 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.

3. 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.

4. 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.

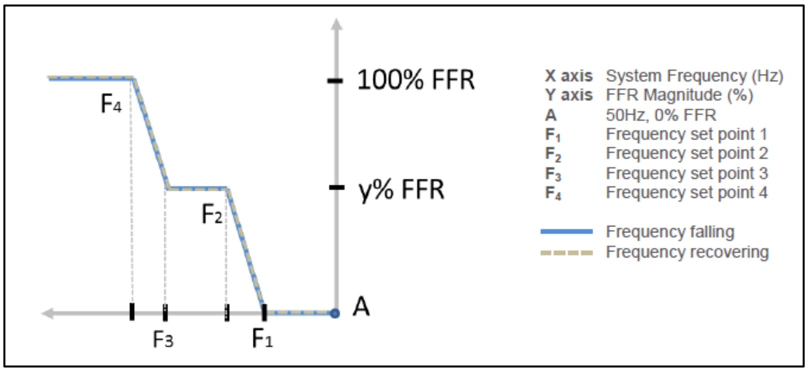

Figure 22: Sample FFR Curve shown in Enduring Scalars Consultation Paper

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.

5. Forecasting of Availability

Similar to other technologies, 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.

6. 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:

a. On /Off Control – The ability for the TSOs to enable / disable operating reserve.

b. Service Availability Declaration – Similar to as discussed in previous sections.

c. Charge remaining (%) signal to notify the TSOs of how much charge is remaining in the Energy Storage Unit.

d. 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.

7. 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

Two trialists participated in the HVDC Interconnector FFR trials. 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 with the following characteristics;

Table 36: Operational Characteristics of HVDC Interconnectors throughout trials

Unit	Type		Droop %	Trigger-point
Unit #1	Dynamic	50MW	2%	49.8 Hz
	Static	25MW	NA	49.5 Hz
Unit #2	Static	100MW	N/A	49.6 Hz

Of the 14 events during the trials, only a subset of the events resulted in the interconnectors being expected to respond, primarily due to trigger points not being reached and also one of the units was on a forced outage for a significant period of the trials.

Table 37: Summary of HVDC Interconnectors Expected Responses

#	Unit 1 Expected Response (Y/N)	Comment	Unit 2 Expected Response (Y/N)	Comment
1	N	Unit Tripped	N	Offline
2	Y	Dynamic only	N	Nadir>49.6Hz
3	Y	Dynamic only	N	Nadir>49.6Hz
4	Y	Dynamic + Static	N	Offline
5	Y	Dynamic only	N	Nadir>49.6Hz
6	N	~ Full Import	Y	
7	Y	Dynamic only	N	Nadir>49.6Hz
8	Y	Dynamic only	N	Nadir>49.6Hz
9	Y	Dynamic + Static	Y	
10	Y	Dynamic only	N	Nadir>49.6Hz
11	Y	Dynamic only	N	Nadir>49.6Hz
12	Y	Dynamic only	N	Nadir>49.6Hz
13	Y	Dynamic only	N	Nadir>49.6Hz
14	Y	Dynamic only	N	Nadir>49.6Hz

It should be noted that although Unit #1 was expected to respond to a number of events, many of the events only touched the 49.8 Hz trigger point so the expected responses were negligible.

Provision of Service

HVDC Interconnectors have shown a strong compliance with the assessment criteria for FFR. A number of examples of this are shown below for illustrative purposes.

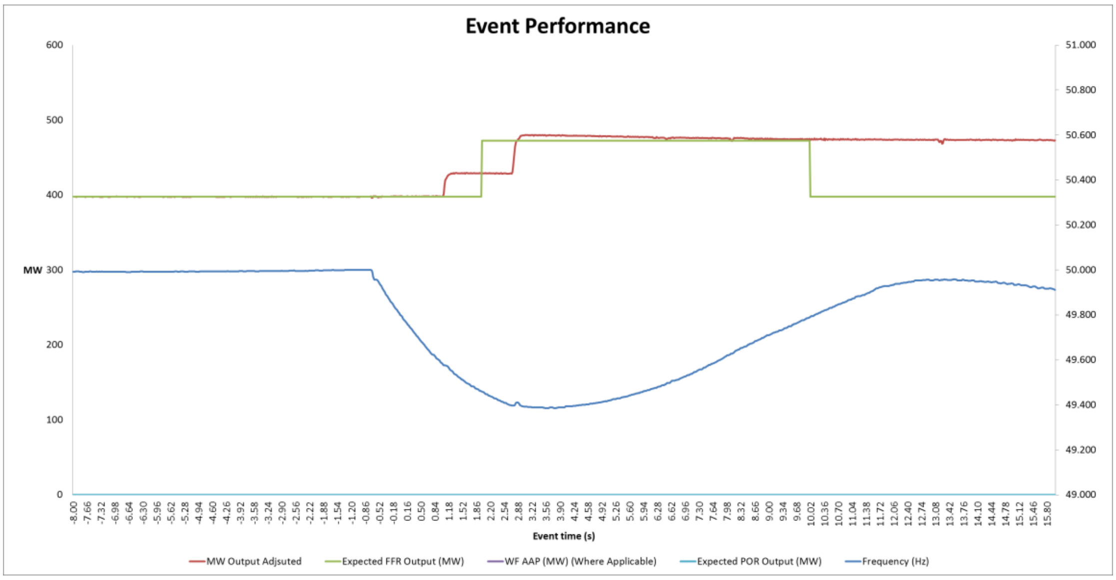

Figure 23: Unit 2 Static Response to Event 20/06/2017

Figure 23 shows a static response to a significant under frequency event. The unit was expected to provide a 25 megawatt blast at 49.6 Hz as well as an additional 50 megawatts should the frequency decrease below 49.4 Hz.

From assessment of the data the unit appears to have given a response in line with its expected output. The unit increases its output by roughly 30 MW following the frequency dropping below 49.6 Hz. The time to detect and provide this response appears to be in the region of 0.25 to 0.3 seconds showing the speed of response possible from HVDC Interconnectors. Similarly, upon the frequency dropping below 49.4 Hz the unit achieves another 51 megawatts of response. The time taken to detect and respond to this volume appears to be roughly 0.35 seconds with the small difference in time attributable to the larger gain in output.

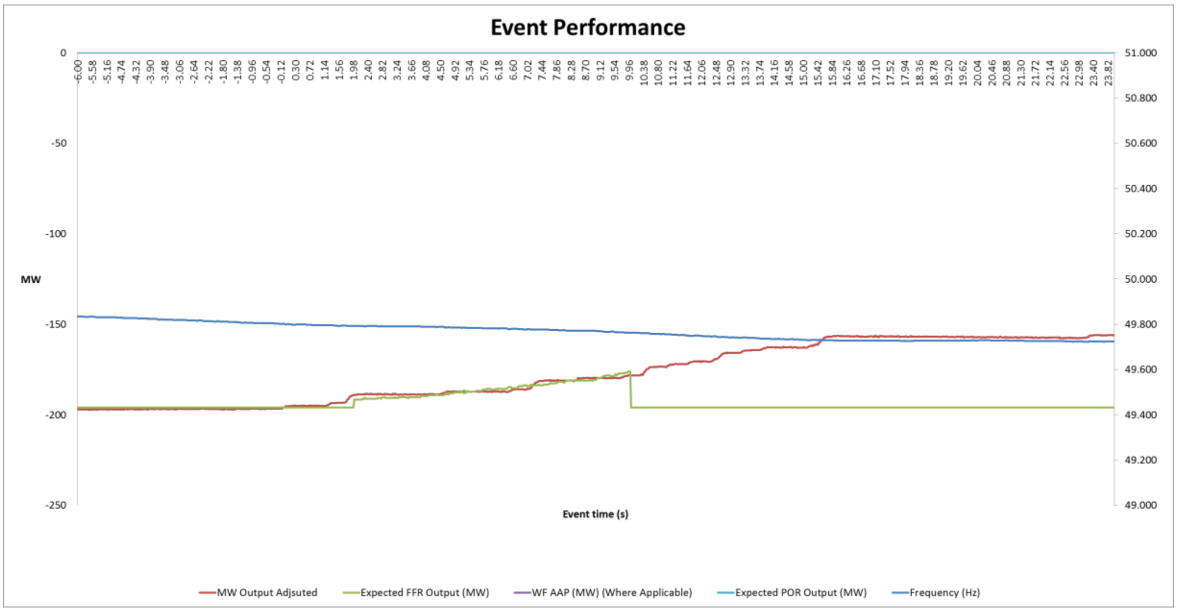

Figure 24: Unit 1 Dynamic Response to Event 18/04/2017

Table 38: Associated table of response values for additional unit to Event - 15/07/2017

	Expected (MW)	Achieved (MW)	∆%	∆MW
FFR Initial	4.25	6.8	**160%**	**+2.55 MW**
FFR Average	10.38	10.8	**104%**	**+0.42 MW**

The unit appears to respond tracking the system frequency within a tight deadband. The initial time taken to detect and begin to respond appears to be in the region of 0.1 seconds, albeit the quantity of response expected is not significant.

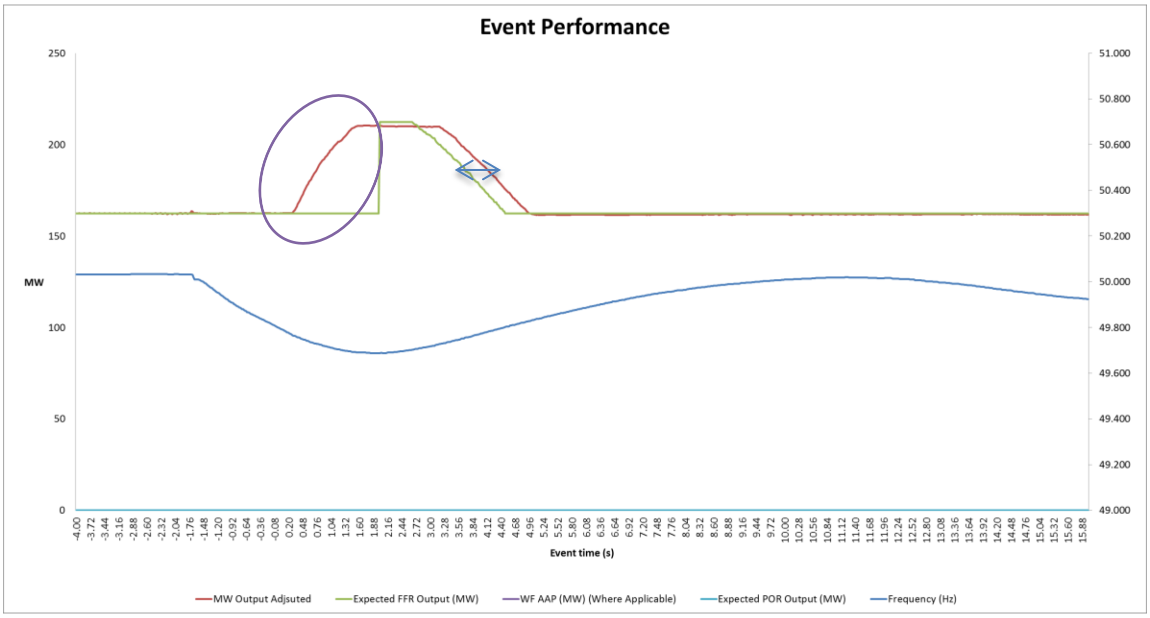

Figure 25: Unit 1 Dynamic Response to Event 23/05/2017

Table 39: Associated table of response values for additional unit to Event - 23/05/2017

	Expected (MW)	Achieved (MW)	Δ%	ΔMW
FFR Initial	50	47.8	**95.6%**	**-2.2 MW**
FFR Average	10.17	12.1	**118.9%**	**+1.93 MW**

Similar to Figure 24, Unit 1 shows an excellent response to the under frequency event on the 23/05/2017. As can be seen in the circled area of Figure 25 the unit's response to the change in frequency takes place significantly in advance of 2 seconds post-triggering.

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 devices - 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.

Provision of Service

One CDGU was contracted to trial the FPFAPR / DRR Services. However, since the beginning of this trial period, this unit has been predominantly run out of merit. Hence, while some voltage dips were recorded on the local disturbance recorder over the trial period, the unit was not connected at the time of any of these and therefore was not expected to respond.

Operational Learnings

Given the lack of event data, the TSOs is minded to consider alternative mechanisms to develop a better understanding of the operational complexities and provision of DRR and FPFAPR Services from CDGUs before considering them a proven technology.

The fact that no events occurred during the trial was in a way a learning in itself. 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.

As part of the trials, one WFPS was contracted to trial FPFAPR and DRR from wind.

Provision of Service

Despite being connected and operational for the majority of the trials only two minor voltage discursions were recorded during the trial. Both showed the wind farm respond. However, as these dips were minor (87% and 88% voltage retained respectively) the response shown were minimal and difficult to measure accurately. As a result, it is difficult to take any meaningful learnings.

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:

Table 40: Minimum Sampling and Time Synchronisation Resolution Accuracy

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%

The minimum standards set out in Table 40 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 41, where “n” denotes the nominal operating point of measurement device installation.

Table 41: Measurement Device Range and Accuracy Standards

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

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 42. The measurement devices must be capable of triggering for this duration in line with the data resolution requirements described previously.

Table 42: Data Triggering Specifications

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

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.

a) 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. Results are presented in Table 43.

Table 43: Comparison of PMU data across four geographically disparsed PMUs

Assessment Method	Value (Hz)
Average Error (10 minute period)	0.001
Average (+/- 10 seconds of Nadir)	0.002
Average (+/- 1 seconds of Nadir)	0.002

Following the assessment of data, the results tended to correlate well across all four PMUs. They showed that the assumption of system frequency being constant during events is accurate within 0.002 Hertz on average.

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:

1. The recorded frequency nadir (Hz); and
2. The recorded frequency nadir time (seconds).

From assessment of the results it became apparent that the time synchronisation 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 synchronisation 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 synchronisation.

b) 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.

c) Installation of Measurement Devices at selected locations

The TSOs may also elect to install their own measurement device at a site of interest. This may occur in cases where a Service Provider is consistently showing issues in relation to a) and b) above.

d) 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.
6. 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 44 shows in detail the findings of this report with respect to provenability.

Table 44: Technologies that can considered as Proven Technologies

Technology Class / Sub Class[6]	Services Applicable[7]
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

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

[6] Explanation of Acronyms and technology classes can be found in Table 5 of this report.

[7] Explanations of these Acronyms can be found in Table 3 and Table 4 of this report.

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.