S&C ELECTRIC COMPANY
Excellence Through Innovation

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Sebastien Henry
Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

Our Ref: JC 2017-001 9 February 2016

Dear Sebastien,

S&C Electric Company submission to the Interim Report on System Security Market Frameworks

S&C Electric Company welcomes the opportunity to provide a response of the development of measures to the support the development of a secure system in the face of increasing Rate of Change of Frequency and decreasing inertia.

S&C Electric Company has been supporting the operation of electricity utilities in Australia for over 60 years, while S&C Electric Company in the USA has been supporting the delivery of secure electricity systems for over 100 years. S&C Electric Company not only supports "wires and poles" activities but has delivered over 8 GW wind and over 1 GW of solar globally. S&C Electric Company has been actively engaged in deploying Battery Energy Storage Systems since 2006 providing a full range of services and using a range of battery technologies and currently has 45 MW/177 MWh in operation, including the UK Power Network's 6 MW battery that provides local peak load support and frequency services to National Grid the GB system operator and the Ergon Grid Utility Support System in Queensland, which reduces peak loads and provides voltage support on rural lines.

We note that Australian Energy Market Commission and Australian Energy Market Operator have a joint technical working group for Power System Security and while there are renewable generators with interests in deploying electricity storage, there is no Battery Energy Storage System specialist to ensure that this established technology can fully contribute to the development of secure, sustainable and low cost power systems in Australia and we would be pleased to participate in this group.

We are particularly interested in facilitating the development of markets and standards that deliver secure, low carbon and low cost networks and would be very happy to provide further support to the Australian Market Energy Commission on the treatment and potential of these technologies.

Yours Sincerely

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Introduction:

Australia's electricity system, in common with many other countries, is changing rapidly as intermittent generation connects at both the distribution and transmission level and as the fleet of large combustion plant reduces in response to both the need to mitigate climate change and changing market signals.

It is difficult to separate the many variables that impact on the operation of a secure electricity system given the independency of inertia and frequency. With the loss of inertia (spinning reserve) the time available to make system adjustments and many of the automated process are dependent on rate of change of frequency values that are now increasing rapidly leading to separations, which may have been avoided.

Other systems, most notably in the USA and the UK, are exploring *very rapid* frequency response, provided by third parties through market approaches, rather than mandated services delivered by already connected large combustion plant.

This response will address the four concurrent Reviews and Proposed Rule Changes:

- EPR0053 – System Security Market Frameworks Review
- ERC0208 – Inertia Ancillary Services Market
- ERC0214 – Managing Power System Frequency
- ERC0211 – Managing Power System Fault Levels

EPR0053: System Security Market Frameworks Review

We agree with the four guiding principles of Risk management, balancing certainty with flexibility, technology agnostic approaches and competition. Electricity systems globally are changing very rapidly and maintaining security requires a flexible approach that can respond quickly and easily to changing network and system requirements.

There may be occasions when a particular technology may be more likely to deliver a particular system service and the specifications for that service may need to be developed collaboratively with technology stakeholders (as was the case with the National Grid Enhanced Frequency Response tender), but the starting point for any specification should always be the technical needs of the system.

Where markets are well-established and do not favour any particular player (and markets where generators receive incentives cannot be deemed to be level for all participants) then competitive tenders in that market are a good way to deliver new system services. Where markets are not level or under developed, then care is needed to ensure that any competitive approach is truly technology neutral. This is a particular issue for new low carbon technologies such as Battery Energy Storage Systems.

Care is needed to ensure that contract length and contract terms are appropriate for new approaches to providing system services and don't exclude, where feasible, the opportunity to access multiple income streams, as contracts of the appropriate length and terms will facilitate the delivery of the service at a lower cost (lower cost of finance is highly dependent on contract length and income).

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The value of the service needs to be appropriate with various models being used internationally. In the USA "accuracy" ensures that a frequency response has a higher value than speed alone. In the UK, speed, counterintuitively, has ended up being less valuable than traditional primary and secondary services. Ireland and Northern Ireland have developed an entire range of new services, which came into force in October 2016, to support operation of the all-Irish system with high wind penetration (http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/). But in all cases the fast frequency response is competitively procured.

We would favour a competitive approach to delivering new system services (option 2), rather than obligating parties to deliver a new service (option 1 and 3). Option 2 would not exclude generators, both conventional and low carbon, from participating and may result in low cost services since existing connectees may be able to leverage existing connections and land holdings.

A five minute spot market (option 4) in fast frequency response or synthetic inertia seems unlikely to provide services that have to be delivered exceptionally fast. Fast response times are typically achieved through dynamic and automated services, following system frequency, which require no signal from the operator.

Synthetic inertia is far harder to provide than fast frequency response and a competitive market approach for fast frequency response in the UK was shown to be quicker to bring to the system than mandated services, which would require a code / rule change process. National Grid's Enhanced Frequency Response took 1 year from Expressions of Interest to tender (6 months longer than expected due to the overwhelming level of interest – The Expression of Interest sought 200 MW and 1.3 GW pre-qualified, the development of service specifications and consultation with the electricity storage industry, but the learning from that process are available):

Sept 2015	Expression of Interest
July 2016	Bids (originally planned for December 2015)
August 2016	Successful tenders confirmed
April 2017	Delivery of first system
19 months total	

We agree that effectively managing Rate of Change of Frequency is an increasing issue, which is being experienced in many systems. S&C Electric company are of the opinion that fast frequency response is the most effective tool for mitigating Rate of Change of Frequency, in the absence of true inertia.

ERC0208 – Inertia Ancillary Services Market

While rapid or enhanced frequency response services are becoming well established, inertia services are less developed. The system inertia provided by synchronously coupled large scale thermal plant is well established and well understood, but the provision of synthetic inertia is less well established. The GB Transmission System Operator determined that a rapid frequency response services was easier to achieve than a synthetic inertia service and the frequency service was likely to be more technically achievable and reliable.

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Wind turbines can, with appropriate pre-installation choices, provide synthetic inertia and Hydro-Quebec, Canada has mandated wind turbines with this capability since 2005, with the wind fleet demonstrating inertia provision in system events and this is well covered in the DGA Consulting report for the Australian Energy Market Operator (International Review of Frequency control Adaption, October 2016). Wind turbines, when mandated at the design stage, can deliver inertia, but this may result in a higher requirement for primary frequency services and while inertia from wind turbines has a beneficial impact on RoCoF, it does not fully resolve the issue of low frequency load shedding (Gonzalez-Longatt F.M*, J. Mod, Power Syst. Clean Energy*, 4, 211-218, 2015)). It is also highly dependent on turbine manufacturer, since there are a limited number of manufacturers who can deliver the required functionality. We note that the Hydro-Quebec approach is bespoke to their system and a great deal of work would be required in Australia to develop the required response characteristic standards.

Battery Energy Storage Systems can also provide synthetic inertia, however the associated control algorithms are less well-established for this service versus very rapid frequency response services. S&C Electric Company uses BESS to provide inertia in its micro-grid and islanding systems, but in these cases the BESS is the voltage and frequency source, as such frequency is inherently regulated by the invertor. S&C Electric Company also has many MW-scale grid-connected BESS in service that synchronise with the voltage wave-form of the grid and follow the system frequency, then inject or absorb power based on an autonomous frequency control algorithm.

ERC0214 – Managing Power System Frequency

While an ancillary services market in frequency response is under developed in Australia, many other power systems around the world have well-developed markets for the provision of many system services from non-mandatory sources. National Grid, the Transmission System Operator in Great Britain has a broad range of balancing services that include dynamic and non-dynamic services such as Mandatory Frequency Response provided by large synchronous generators, including pumped hydro, Frim Frequency Response (FFR) and Frequency Control by Demand Management (FCDM). In late September 2015 the GB TSO announced its intention to procure 200 MW of Enhanced Frequency Response (EFR), with a sub-second response time.

Enhanced Frequency Response was developed to address falling system inertia as result of the loss of large combustion plant from the GB system, as a result of the EU Large Combustion Plant Directive, covering particulate emissions. Additional capacity has also been secured through the UK Government “Capacity Market”, with varying degrees of success, since the desired new large gas turbine plant has not materialised under the Capacity Market.

GB’s fastest responding asset is the 1.7 GW Dinorwig pumped hydro plant in NW Wales, with a response time of 5-6 seconds. Prior to the connection of intermittent generation to the GB system, there were 12 seconds available to respond to a major frequency event. This has now reduced to close to 6 seconds and directly led to the TSO’s desire to procure a sub-second frequency service.

The Enhanced Frequency Response tender allowed for a collaborative development approach from potential providers and the Transmission System Operator. The final tender in July 2016 saw 10 successful bids for a total of 201 MW of Enhanced Frequency Response, delivered at a cost to the Transmission System Operator of GBP66M (AUD107M) over the four year life of the contracts and the Transmission

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System Operator estimates that this new service will save the end consumer GBP200M (AUD325M) in balancing costs over the same period.

The new Enhanced Frequency Response service was very attractive to new providers (some established conventional generators/suppliers, but many new players), resulting in 20 GW in new connection requests for electricity storage to the distribution system in GB. Since the specified size of the Enhanced Frequency Response assets was in the range of 10-50 MW, connections were all sort on the distribution system and the lack of coordination and the 100 % availability requirement for the Enhanced Frequency Response service placed a huge and unexpected burden on the distribution network operators in the UK, analogous to Australian Network Service Providers. There were a number of proposed 200 MW battery projects that sought to connect to the GB transmission system, but the Transmission System Operator settled on a maximum size of 50 MW and these projects did not go forward, but interest in batteries of 100-200 MW on the GB system is still high.

Frequency Service	**Response**	**Sustained**	**Minimum Size**
Mandatory:			
Primary	10 s	± 20 s	
Secondary	30 s	± 30 m	
High	10 s	- indefinitely	
FFR	as instructed	as instructed	± 10 MW
FCDM	2 s	- 30 m	3 MW (aggregation possible)
EFR	< 1 s	9 s to 45 m	± 10 MW to 50 MW maximum

FREQUENCY SERVICES IN THE GB SYSTEM

See http://www2.nationalgrid.com/uk/services/balancing-services/frequency-response/ for further detail on routine frequency and http://www2.nationalgrid.com/Enhanced-Frequency-Response.aspx for further details on Enhanced Frequency Response.

All of the successful tenders were based on Li-ion battery technologies and while this may appear to be a relatively untested technology, there is a great deal of experience in the USA markets where utilities have been mandated to deploy storage to provide system services and in the UK, UK Power Networks have been operating a 6 MW Li-ion battery for over 2 years to provide peak shaving (avoiding reinforcement) and frequency services.

The advantages of electricity storage are that it can be rapidly deployed, can respond rapidly to deliver services and can "shape" delivery to dynamically and accurately meet system needs. Enhanced Frequency Response assets are expected to be operational within 8-18 months and Battery Energy Storage Systems can deliver upward and downward regulation dynamically and automatically within 100 ms.

Requiring existing generators, both conventional and renewable to retro-fit additional frequency support will dramatically impact on the economics and operation of the existing plant. The European Union is now requiring *newly* connecting renewable generators to provide a range of frequency services (Network Code on Requirements for Generators, RfG: https://www.entsoe.eu/major-projects/network-code-development/requirements-for-generators/Pages/default.aspx), based on size, to the TSOs and the approach of requiring *new* projects to provide system support services is much more equitable than

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seeking to retrofit equipment to deliver services, but further consultation with the generation community is required.

The GB Transmission System Operator determined that a new competitive ancillary service could be delivered more quickly through standard ancillary market approaches and with no need to change the mandatory requirements (code change) for generators.

However, in the UK, many of the potential providers of Enhanced Frequency Response were existing generators, mainly solar PV, with connections and land and indeed a number of the successful bidders are conventional and renewable generators where existing connections and land provide cost benefits to delivering a new battery project. Unfortunately, the structure of the current low carbon generation incentive schemes in the UK make the retrofit of storage to an existing site challenging in terms of retaining the incentive and connection. The newer Contracts for Difference incentive scheme is in the process of providing guidance on the incorporation of storage onto renewable generation sites, with the aim of ensuring here are no barriers.

Rapid frequency services can be provided by distribution network operators (network service providers) lowing or increasing voltage on their networks. This was trailed on the Great British (GB) system in an Ofgem Low Carbon Network Fund (LCNF) innovation project: Customer Load Active System Services (CLASS: http://www.enwl.co.uk/class#). Electricity Northwest managed voltage on their network to provide frequency and voltage control to the GB Transmission System Operator. The project concluded that there was 3.3GW of demand response, the equivalent to two combined cycle gas turbine (CCGT) power stations and up to 2GVAr of reactive power absorption at distribution level across the whole of GB. The results have shown that there are possibilities for the NSP (DNO) to enter the frequency and enhanced reactive power markets, proving an alternative, low cost, carbon saving and flexible solution to the Transmission System Operator for ancillary services when compared to the existing costly and carbon intensive methods. Further, GB quality standards currently allow this variation of voltage to customers, but some adjustment of the quality and security of supply standards would allow for a broader application of the CLASS approach.

The GB Grid Code obliges a Distribution Network Operator to provide a demand response to Transmission System Operator for the management of frequency, delivered by the 3% or 6% voltage reduction at Distribution Network Operator substations; but this is generally called upon when other generation and demand management options such as Short Term Operating Reserve (STOR) have been exhausted. There is no base case for the commercial provision of demand response for frequency reserve or reactive power for voltage control from a Distribution Network Operator to the Transmission System Operator. This is because the current regulatory model in GB disincentivises such activities. An assessment as part of the project suggested that the potential revenues from the provision of these network services to Transmission System Operator could be in the region of AUD40.6M per annum, if the CLASS Solution was applied GB-wide and these revenues would flow directly to Distribution Network Operator customers through reduced bills from lower Use of System charges.

While the ownership and operation of electricity storage by an Network Service Provider is complex in Australia (And many other systems) due to regulatory arrangements, particularly the new ring-fencing requirements, in other systems, including in Europe and the UK, ownership and operation of batteries by

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NSPs is permitted after the market has failed to deliver and batteries deliver the lowest cost solution to the end customer. Additionally, it is not immediately clear whether an Network Service Provider in Australia could provide a commercial ancillary service to the Transmission System Operator, but the CLASS approach may be a way to provide system support and merits further assessment. The Network Service Providers could be obligated to provide such services (option 3), but the CLASS approach is not without costs, which would need to be recovered.

ERC0211 – Managing Power System Fault Levels

In some locations in Australia system strength is reducing, characterised by low fault currents, which reduces the effectiveness of protection systems that detect and clear faults, and the ability of inverter-connected plant to operate as designed. Low fault currents could also result in greater difficulty in maintaining stable voltage levels in some parts of the network.

Some Battery Energy Storage Systems (BESS) Power Conversion Systems (PCS) possess short term overload functionality that enables the Battery Energy Storage System to contribute to fault currents at approximately 200 % of nominal output for short periods (typically up to 5 s), however this is a limited response in the context of a much larger power system, but may be a useful contribution in some locations. A Battery Energy Storage System is a highly effective method of dynamically regulating voltage through the injection of real and or reactive power, depending on what is most suitable in any given situation.

Given the complexity of managing fault levels, which is highly dependent on the type of connectee, the location and the state of the system at that location, it would seem appropriate that the management responsibility is with the party with the greatest over-sight of the networks. A connected generator or BESS may strive to meet code requirements, but fail due to changes in the surrounding network and the connectee may be unaware of those changes. It is likely that only network operators and the Australian Energy Market Operator will have the necessary network or system oversight to properly manage fault levels and as this becomes an increasing issue, it will be critical that the responsibility to maintain fault levels should be clearly assigned to specific system actors. This will necessitate the development of appropriate codes and standards. In GB the Transmission System Operator is required to manage fault level on the transmission network, while the Distribution Network Operators are required to manage fault levels on their networks.

Summary

In summary, Battery Energy Storage Systems have been shown to be able deliver sub-second frequency response in a number of systems, including in the USA, Ireland and GB. In all cases the frequency response service has been procured via a tender process from third parties, resulting in a mix of stand-alone storage assets and storage assets deployed behind existing connections on conventional and renewable generation sites.

We would strongly support the creation of a new market for fast frequency response (option 2), since by going to the market with either specific service requirements or collaboratively developing service requirements with the industry, many Transmission System Operators around the world have been able

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to deliver low-carbon frequency support services, that are extremely responsive and flexible, and at lower system cost than through conventional approaches (which can't respond as rapidly or as accurately as batteries). The GB Enhanced Frequency Response tender will deliver 201 MW of sub-second frequency response at a cost of AUD107M over four years (AUD26.8M per year), with an estimated saving of AUD325M to the end consumer. Battery Energy Storage System projects can be deployed in 12-18 months allowing system issues to be resolved more rapidly than might be the case with conventional approaches. By developing a market the widest range of providers will be engaged, some who are generators, some who are storage developers, without the need to obligate generators to deliver the service (option 1).

Additionally, if the service and contract requirements, such as availability, are shaped carefully to allow a Battery Energy Storage System to deliver multiple services through income stacking, other system benefits may be achieved from a single asset resulting in system efficiencies. Although it should be noted that many of the successful GB Enhanced Frequency Response tenders (at an average of AUD15.35 per MWh of Enhanced Frequency Response per hour) are understood to be priced to ensure that the full cost of the project will be recovered within the four life of the Enhanced Frequency Response contract – noting that bid piece were a lot lower than was originally anticipated (AUD24-33 per MWh of Enhanced Frequency Response per hour) and considerably lower than tenders for conventional frequency response services on the GB system.

S&C Electric Company has over 10 years' experience in deploying and operating utility scale and utility grade Battery Energy Storage Systems globally and has deployed such systems in the a wider range of applications and use cases than any Energy Storage provider. Use cases include peak shaving, market driven frequency regulation, autonomous frequency response, renewable smoothing, energy shifting, voltage and VAR support, islanding, black start and reinforcement deferral. S&C Electric Battery Energy Storage System solutions have been providing frequency regulation since 2011, so this is an established and proven technology for this application. We would be happy to meet with the Australian Energy Market Commission and Australian Energy Market Operator to share our experience with deploying and operating Battery Energy Storage System for supporting power systems.