21 April 2023

Dear AEMO team

AEMO review of technical requirements for connection under Schedules 5.2, 5.3 and 5.3A of the NER

Tesla Motors Australia, Pty Ltd (Tesla) welcomes the opportunity to provide the Australian Energy Market Operator (AEMO) with feedback on the Draft Report making recommendations for amendments to Schedules 5.2 and 5.3A of the National Electricity Rules (NER). We appreciate the work that has been done by AEMO on developing such a detailed list of amendments, and appreciate the thought that has gone into how to make the connection process easier for inverter based resources, particularly grid-forming inverters. Grid-forming inverters, particularly battery energy storage systems (BESS) will play an increasingly important role in providing system strength and inertia services as existing synchronous plant retires at a rapid rate.

Tesla feedback on each of the recommendations below, with a specific focus on opportunities where additional clarifications or amendments will provide even more support for the uptake of new generation, BESS assets and grid-forming inverters more broadly.

For further discussion or clarification on any of the points included in the response below, please contact Emma Fagan (efagan@tesla.com).

Rule	Issue	AEMO recommendation	Tesla feedback
S5.2.1	Application of Schedule 5.2 based on plant type instead of registration category and extension to synchronous condensers	Replace all the references to Generators or Integrated Service Providers in NER Schedule 5.2 with another defined term (e.g. connected participant or Registered Participant), to apply the schedule more generally, with appropriate interpretation clauses to confirm the meaning of the term in the context of the schedule3 . Corresponding changes may be required elsewhere in the NER, to the extent the access standard schedules and associated performance standards are referenced elsewhere in Chapter 5 or in other defined terms Amend NER S5.2.1 to provide that references to generating systems, synchronous generating systems and synchronous generating units are taken to include synchronous condensers, with a list of exceptions also specified in NER S5.2.1.	N/A

S5.2.5.1	Voltage range for full reactive power requirement	Modify the AAS to include a voltage-dependent requirement for reactive power: • Limit the requirement for full reactive power capability to a 10% voltage band around a centre point nominated by the NSP. • For voltages within the 10% voltage band, require 0.395 x Pmax reactive injection and absorption. • For voltages below the 10% voltage band down to 90%, require 0.395 x Pmax reactive injection. • For voltage from the lower limit of the 10% voltage band to 90%, the requirement for reactive absorption decreases linearly with decrease in voltage from -0.395 x Pmax to 0 MVAr. • For voltages above the 10% voltage band up to 110%, require 0.395 x Pmax reactive absorption. • For voltage above the upper limit of the 10% voltage band to 110%, reactive injection reduces linearly from 0.395 x Pmax to 0 MVAr.	Tesla is supportive of the lower bands. We do, however, have concerns as to how NSPs nominate a voltage. We want to avoid a situation where NSPs have full flexibility in nominating their own voltage centre point. For transparency and consistency we would suggest that the 10% voltage band is centred around the “nominal voltage”, which is nominated by NSP as of the existing Rule. normal voltage defined in NER: *“In respect of a connection point, its nominal voltage or such other voltage up to 10% higher or lower than nominal voltage, as approved by AEMO, for that connection point at the request of the Network Service Provider who provides connection to the power system.”*
	Treatment of reactive power capability considering temperature derating	Clarify that for the purpose of NER S5.2.5.1, the rated active power or rated maximum demand must take account of the temperature dependency of the rating, and that the required Qmax and Qmin are functions of Pmax as derated. That is, Qmax (T) = 0.395 Pmax (T), and Qmin (T) = -0.395 Pmax(T) for operating temperature T at the connection point, for reactive power absorption. Require the performance standards to document: • Active power derating of production units as a function of temperature, if any. • Reactive power derating as a function of temperature of production units and any other reactive power facility, if any. • Maximum operating temperature and minimum operating temperature of the generating system or IRS. • Maximum operating temperature for which the plant is not derated.	As a point specific to a battery energy storage systems, derating is not necessarily a factor directly of temperature. It’s related to a number of other factors. We are supportive of capturing the maximum operating temperature in the GPS. However we are not supportive of capturing derating for above the maximum operating temperature within the scope of the GPS. That should be an engineering discussion that considers the range of factors that influence derating of output above the maximum temperature range.

		• Reactive power performance requirement as a function of active power at the connection point at the maximum temperature for which the plant is not derated. • Reactive power performance requirement as a function of active power at the connection point at the maximum operating temperature, where different. • Reactive power performance requirement at the connection point as a function of temperature.	
	Compensation of reactive power when units are out of service	Amend as follows: • Remove requirement to restrict the reactive range where the voltage impact of the generating system or IRS with units not in service is less than a voltage threshold (to be defined). • Where the Generator or IRP and the NSP agree to limit the range of reactive power at the connection point by means of a subset of production units operating in voltage, reactive power or power factor control, compliance is assessed as if the control is a secondary mode of operation under S5.2.5.13. • Maximum active power consumption of a generating system or integrated resource system in respect of auxiliary load and the range of permitted reactive power at the connection point to be specified as steady state values.	N/A
S5.2.5.1, S5.2.5.5, S5.2.5.7, S5.2.5.8, S5.2.5.10	Simplifying standards for small connections	Amend as follows: • S5.2.5.1 AAS: Set the reactive power required for injection and absorption to be the lower of 0.395 x Pmax and the reactive power that would give rise to a [5%] voltage change, for generation connected to a distribution network. • S5.2.5.5 AAS, MAS: Exempt synchronous and asynchronous generating systems and IRS less than [30] MW connected at MV or LV level, from assessments related to reactive current injection.	Tesla supports these recommendations. We're likely to see a number of smaller connections driven by community storage tenders and other projects. This will simplify the connection process.

		• S5.2.5.7 AAS, MAS: Exempt generating systems and IRS less than 30 MW from this clause in both automatic and minimum access standards. • S5.2.5.8 MAS: See the related proposal for this rule. • S5.2.5.10 See the related proposal for this rule. • In the definition of AEMO Advisory Matters, exclude connections less than 30 MW.	
NER S5.2.5.2 – Quality of electricity generated	Reference to plant standard	Remove reference to AS1359.101(1997) in respect of a synchronous generating unit as a plant standard for harmonic voltage distortion	Tesla is supportive in principle of this change.
S5.2.5.4	Overvoltage requirements for medium voltage and lower connections	Amend the AAS to make the point of application of overvoltages the nearest HV transmission location, for MV connections not through a transformer with onload tap changes, and amend S5.2.5.4(c) to a threshold consistent with the largest generator contingency in the region.	Tesla is supportive of this change.
	Requirements for overvoltages above 130%	AEMO recommends that risk to generators of this clause be bounded. Given the complexities of the issue, AEMO is seeking input from its stakeholders into the most appropriate method of addressing this issue, which may be one of the identified options or an alternative.	Tesla would suggest an alternative that could be considered is to delete S5.2.5.4(a)(1) which would effectively create an upper bound of 130%. Alternatively we would be supportive of Option 4 which would see the introduction of an upper-voltage limit of 140%
	Clarification of continuous uninterrupted operation in the range 90% to 110% of normal voltage	Specify that for the purposes of NER S5.2.5.4(a)(6) subject to energy source availability, reactive capability must be maintained, and active power not materially reduced, for voltages in the range 90 to 110% of normal voltage for voltage variations up to 10% within 5s, within the reactive power range and voltage range specified in S5.2.5.1.	Tesla is supportive of this change. As per comments on S5.2.5.1 above, we would also like to see these bands linked to nominal voltage rather than an NSP defined centre point.

S5.2.5.5	Definition of end of a disturbance for multiple fault ride through	Specify that the end of a power system disturbance, for the purpose of multiple fault ride through (MFRT) assessment, is the time when, following fault clearance, the voltage recovers to and remains within the range 90 to 110% of normal voltage at the connection point for at least [20ms].	Tesla is supportive of this change and believe it provides a helpful clarification.
	Form of multiple fault ride through clause	Amend as follows: • A suite of tests, established by AEMO, incorporating the MFRT requirements under the AAS and MAS. • A requirement on the proponent to apply the tests considering the range of fault levels nominated at the connection point by the NSP, and using the site-specific settings proposed for the plant. • A requirement on the proponent to declare in proposed performance standards any impediment to MFRT, and provide evidence to support the declaration. • A requirement that compliance with the performance standard is to be demonstrated by performance against the test suite and, throughout the life of the plant, not tripping for any undeclared impediment, checked by verifying the cause of any applicable trips during multiple disturbance events.	Tesla is supportive of the proposed approach of AEMO developing a suite of tests that incorporate the MFRT requirements. However, this solution will be far more scalable where the tests are consistent and there is no need to consider site specific settings for a particular plant. In the absence of site-specific settings, OEMs would be able to undertake lab-tests against the AEMO test suite which can be used to support multiple projects. Site-specific settings will not be relevant to MFRT capability.
	Number of faults with 200 ms between them	Retain for the MAS, up to six faults and 200 ms and combination but allow specific limitations such as technology-related limitations (but not limitations arising from inadequate tuning) to be carved out of these requirements for modelled and non-modelled limitations. This allows flexibility while minimising the carve outs from present requirements. It also promotes efficient connection as it can be programmed into the proposed common test suite.	Tesla is supportive of this change and the proposed carve-outs.
	Reduction of fault level below minimum level for	Amend as follows: • Carve out from the MFRT conditions for continuous uninterrupted operation (CUO), in both the AAS and MAS, conditions where fault	In respect of NSP plant retuning, Tesla is only supportive of this approach if there is a clear MFRT carve-out in the 5.3.9 amendment process. We would not support any retuning if it involved a full 5.3.9 review. There is precedence for this

	which the plant has been tuned	levels fall below the lower bound of the fault level range for which the plant has been tuned. • Require that the range of fault levels for tuning be advised by the NSP and recorded, along with (but not within) the performance standards Enable the NSP to require retuning of the plant, where changes to fault level on the power system could cause the plant to be unable to remain in continuous uninterrupted operation for multiple disturbance.	approach with the introduction of PFR resulting in a limited 5.3.9 amendment process with clear guardrails. Any NSP retuning linked to MFRT should be treated in a similar manner to reduce inefficient spend and the considerable time taken in working through a full scope 5.3.9 review process.
	Active power recovery after a fault	Change the AAS, substantially consistent with the MAS changes, subject to minor amendments proposed by AEMO in response to the ERC0272 draft determination. In the final report for this Review, consideration will need to be given to how AEMC's final determination deals with frequency response, inertial response and active power response to phase angle changes.	Tesla is supportive of this change.
	Rise time and settling time for reactive current injection	Amend as follows: • Omit settling time for the AAS. • Replace adequately damped with adequately controlled. • Qualify that rise time is to be measured for "step-like" voltage profile at the production unit terminals. • Add a commencement time requirement, less than 10 ms, with response in a direction that opposes the change in voltage at the production unit terminals.	Tesla is very supportive of the recommendation to omit settling time from the AAS. In respect of the recommendations made for rise-time requirements we would recommend one of the following options: • Align with the final changes made to the minimum access standard in ERC0272 which has a commencement time standard that requires a reactive current response to start within **40ms** of a fault (rather than 10ms); or • Include additional clarifying language that specifies that that the commencement time is less than 10ms **from the time the voltage drop is measured at the connection point.**

	Commencement of reactive current injection	Specify that reactive current response to an undervoltage event commence above 85% of normal voltage at the connection point, and for an over-voltage event commence below 115% of normal voltage at the connection point.	Tesla is supportive of this change.
	Clarity on reactive current injection volume and location and consideration of unbalanced voltages	Amend as follows: • Clarify that the GPS should record the capability provided by the facilities and the settings for reactive current injection that are implemented. • Clarify that the settings should be set to minimise the voltage deviation on each phase from its pre-disturbance value, subject to maintaining stable operation over the expected range of system impedance levels. • Require that the reactive current injection capability be assessed for positive sequence values. • Require documentation of the negative phase sequence injection.	Tesla is mostly supportive of this proposed change, however we make the following recommendations in respect of Option 5 and the question asked by AEMO on negative sequence – we would recommend that instead of defining the ratio of negative sequence, current should be defined as a function of negative sequence voltage. Alternatively, the negative sequence current injection should be outcome-focused. For example, supply sufficient negative sequence current during an unbalanced fault to ensure that the healthy phase voltage does not rise above 1.10 pu.
	Metallic conducting path	Remove NER S5.2.5.5(a) on the basis that existing wording does not appear to add anything useful to the clause	Tesla agrees with this deletion and the general comments that it is low importance.
	Reclassified contingency events	Expand the credible contingency reference by reference to specify credible contingency events selected by the NSP for the purpose of NER S5.1.2.1 (credible contingency events).	Tesla supports this change in principle and believes it will provide some helpful market clarifications. However we would suggest that this list of credible contingency events provided/ selected by the NSPs are as detailed as possible, with a list of specific contingencies provided relevant to the region or connection point, published in NSP's planning report. This information will be helpful.
S5.2.5.7	Application of minimum generation to	Amend the clause to refer to generating units for the carve out about operating above minimum generation	Tesla is supportive of this change

	energy storage systems		
	Clarification of meaning of continuous uninterrupted operation for NER S5.2.5.7	Replace the term “be capable of” with “remain in”.	Tesla is supportive of this change
S5.2.5.8	Emergency over-frequency response	Amend as follows: • Make paragraph (2) apply only if the plant does not provide primary frequency response consistent with the Primary Frequency Response Requirements (published under NER 4.4.2A), considering deadband and droop. • Change the reference from “upper limit of the extreme frequency excursion tolerance limits” to “0.5 Hz less than the upper limit of the extreme frequency excursion tolerance limits”. • Remove the reference from “not less than the upper limit of the operational frequency tolerance band”. • Add a carve out for the 3 seconds requirement in (a)(2)(i)(B) and (a)(2)(ii), so that where AEMO agrees that the physical attributes of the plant do not allow it to meet the time constraints of these rules, a longer time can be specified consistent with the fastest active power ramp down rate for safe operation. • Apply the same size threshold irrespective of nature of plant – 30 MW.	Tesla is supportive of this change.
S5.2.5.10	Requirements for stability protection on asynchronous generating systems	In the AAS, specify that a generating system or IRS, for its asynchronous units: • Must have a protection system that can detect an instability and disconnect the production unit based on its nominated settings such as disconnection time and oscillation magnitude.	Tesla is partially supportive of this change. We support the recommended requirements around PMUs being connected. However we are not supportive of the recommendation made to have capability to disconnect, as automatic disconnection can pose higher system security risk.

		• May take corrective actions such as ramping down or changing control mode (where the thresholds and corrective actions, are to be coordinated by the NSP). • The generating system or IRS must have a detection device to identify whether the production unit or system is contributing to the instability or (subject to the agreement of the NSP and AEMO) a PMU connected to the unit or system capable of providing information to a central system to identify if the unit or system is contributing to an instability. Where a central system is used, the generating system or IRS must have the capability to accept information on contribution from the central system. • The generating system or IRS must have a PMU, regardless of whether a centralised system for determining contribution to an oscillation is used. The PMU would need to monitor and analyse the active power, reactive power and voltage at the plant, and provide the results to AEMO and the NSP. The MAS, for a generating system or IRS [20 MW] or more, would require: • For generating systems or IRS greater than 20 MW, its asynchronous units, a protection system to disconnect for instability or sustained oscillatory response in active power, reactive power or voltage. • For its synchronous units, to have a protection system to disconnect a synchronous generating unit for pole slipping. • Have capability to accept a trip command from AEMO or the NSP In the MAS, • Require a monitoring system for active power, reactive power and voltage, capable of providing timestamped data to the NSP and AEMO. • Not require a detection device to identify whether the production unit or system is contributing to the instability. • Remove reference to AS/NZS 61000.3.7:2001 from the MAS. In addition, remove to AS/NZS 61000.3.7:2001 from the MAS.	Given the bidirectional nature of battery energy storage systems, there are very few circumstances where a system disconnection will be necessary, if a disconnection or trip signal is sent to generation assets, battery energy storage systems and bi-directional assets could be sent a charge signal.

S5.2.5.13	Voltage control at unit level and slow setpoint change	Amend as follows: • To clarify that voltage, reactive and power factor control may be implemented at production unit level, for both synchronous and asynchronous plant. • Specifically allow rate-limited setpoint change of the generating system. Bypass rate limiting during testing to assess stability of the controls. The changes would apply to both synchronous and asynchronous plant. The slow setpoint change amendment would apply to voltage, power factor and reactive power modes.	Tesla is supportive of this amendment. However, we would suggest that instead of specifying a rate-limit setpoint change, we would recommend also including a low-pass filter as an option.
	Realignment of performance requirements to optimise power system performance over expected fault level (system impedance) range – Voltage control	Require that the range of system impedances for which the plant is tuned be recorded in the releasable user guide. In the AAS: • Require a 2 second rise time of reactive power for a 5% setpoint change for the highest system impedance level nominated by the NSP. • Retain a 5 second settling time (5% step not into a limit) and 7.5 s settling time (5% step into a limit). In the general requirements: • Where 5 second settling time cannot be met at both minimum and maximum system impedance, control tuning should be set to achieve AAS level settling time for maximum system impedance and target as close to AAS level settling time as possible for highest system impedance, and settling time for low, typical and high system impedances to be recorded in the GPS. • The typical system impedance level should be reflective of typical dispatch levels. • Similar clarifications as those proposed for the general conditions for voltage control, should be applied for reactive and power factor modes where settling time cannot be met at minimum and maximum system impedance conditions with the same control tuning settings. In the MAS:	Tesla accepts the majority of proposed changes in respect of system impedances. We would suggest that it would also be valuable for AEMO to consider aligning the approach taken for rise time and settling time with different rise times specified for into a limit (proposed 4 second) and not into a limit (2 seconds as per the AEMO proposed amendment). In respect of the proposed amendments to the MAS – would AEMO consider replacing the settling times with a requirement to be adequately damped.

		• Retain settling times as per existing MAS for highest system impedance level. • Allow a higher settling time for lowest system impedance level, provided the response is critically or over-damped. • Where the MAS settling time cannot be met at both highest and lowest system impedance, settling times for highest, typical and lowest impedances are to be recorded in the GPS. In addition, apply the same approach to the synchronous machine requirements for settling times only (as there is no rise time requirement for synchronous generating systems).	
	Materiality threshold on settling time error band and voltage settling time for reactive power and power factor setpoints	Amend as follows: • Remove the calculation of voltage settling time for reactive power and power factor modes. • Assessment of active power settling time is not applicable for voltage, voltage setpoint, reactive or power factor steps when the maximum change in active power is less than 5 MW.	Tesla would suggest a slight amendment to the AEMO wording such that the "change in active power is less than 5MW **<u>or less than 2% of the plant rating. Whichever is the highest."</u>**
	Clarification of when multiple modes of operation are required	Require two modes in the AAS: • With the ability to switch between them • Where primary mode is voltage control • Where secondary mode either power factor or reactive power • With reduced assessment requirements for secondary mode: – remove the requirement for settling time compliance assessment for power factor and reactive power setpoint changes – retain the requirement for settling time assessment for voltage disturbances.	Tesla is supportive of the reduced assessment requirements.
	Impact of a generating system	Amend as follows:	Critical fault of oscillation required by the NSP. Critical modes need to be identified though NSP's system studies. The system study results, including critical faults, system conditions, and oscillation modes should be published in

	on power system oscillation modes	• Modify the AAS to require facilities capable of providing positive damping for system strength sensitive critical modes of oscillation identified by the NSP. • Modify the MAS to require it not to exacerbate any mode of oscillation beyond the point at which it would be adequately damped or to exacerbate any oscillation that is not adequately damped. • Carve out the damping requirements of MAS (d)(1) pertaining to system-strength sensitive oscillations (only) where the Generator or IRS has opted to pay for system strength services to be provided by a SSSP	NSP's planning report. Similar to the credible contingency event recommendation above.
	Recognition of frequency response mode, inertial response and active power response to an angle jump	Modify the CUO definition or relevant clauses to: • Permit responses opposing voltage phase angle jumps and frequency changes, including inertial response during disturbances, in clause (b). • Permit inertial response and response opposing voltage phase angle jumps and inertial response, after clearance of any fault, in clause (c). • Take into account inertial response and response to voltage phase angle jumps for subsequent response, in clause (d).	Tesla is supportive of this change
S5.3a.1a	Alignment of schedule with plant-type rather than registration category	Apply the requirements of Schedule 5.3a to all to HVDC systems irrespective of registration classification.	Tesla is supportive of this change
S5.3a.8	Reactive power	Align the reactive power capability requirements for HVDC systems with those for generators in NER S5.2.5.1, noting the proposed changes to NER S5.2.5.1 for generating systems.	N/A
S5.3a.13	Voltage disturbances	Align the voltage disturbance power capability requirements for HVDC systems with those for generators in NER S5.2.5.4, considering the proposed changes to NER S5.2.5.4 for generating systems discussed in this report.	N/A

	Frequency disturbances	Align frequency disturbance power capability requirements for HVDC systems with those for generators in NER S5.2.5.3, including the RoCoF requirements, noting the proposed changes to NER S5.2.5.3 for generators discussed in section 4.5 of this report. Exempt NSPs from the requirement of NER S5.1.3 to align with the recommended requirements for all HVDC systems.	N/A
	Fault ride through requirements	Align fault ride through and MFRT capability for HVDC systems with those for generators in NER S5.2.5.5, noting the proposed changes to NER S5.2.5.5 for generating systems discussed in this report.	N/A
S5.3a.4	Remote monitoring and protection against instability	Align remote monitoring and protection against inverter instability requirements for HVDC systems to the equivalent requirements for generating systems in NER S5.2.5.10.	N/A
New standards	Voltage control	Align AC voltage control capability for HVDC systems with those for generators in NER S5.2.5.13, noting the proposed changes to NER S5.2.5.13 for generating systems discussed in this report.	N/A
	Active power dispatch	Align active power control requirements for HVDC systems with those for generators in NER S5.2.5.14, including for dispatch and ramping.	N/A
Multiple	References to superseded standards	Amend the references to AS/NZS 61000.3.6 and AS/NZS 61000.3.7 (with or without dates) in S5.1.5, S5.1.6 S5.1a.5 and S5.1a.6 to the latest versions TR IEC 61000.3.6 and TR IEC 61000.3.7, without dates	N/A