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Australia

Mr John Kim
Senior Adviser
Australian Energy Market Commission
PO BOX A2449
Sydney South NSW 1235

6 February 2025

Dear Mr Kim,

Re: Tesla Submission – Efficient Provision of Inertia

Tesla Motors Australia, Pty Ltd (Tesla) welcomes the opportunity to provide the Australian Energy Market Commission (AEMC) with our submission to the Efficient Provision of Inertia Directions Paper.

Tesla's mission is to accelerate the transition to sustainable energy. A key aspect of this will be using smart, grid-forming inverters to support increased penetration of variable renewable energy (VRE) in the grid. We believe that battery energy storage system (BESS) assets, particularly Tesla Megapacks operating with our virtual machine mode (VMM) technology, will be integral to providing a scaled, cost-effective inertia and system strength solution in all Australian jurisdictions.

As such, Tesla welcomes the Directions Paper reviewing the suitability of operational procurement mechanisms and is aligned with taking different approaches for minimum and additional inertia. In addition to responding to the consultation questions, this response includes feedback on the design paper. Tesla's summary of key considerations are as follows:

- **Role of grid forming inverters (GFI)** – lowering fixed costs of inertia supply, maintaining static inertia constants.
- **Market approach for additional inertia** – support market as dynamics will improve efficiency and lower costs.
- **Market design feedback** – modelling considerations in NEMDE for FFR and inertia.

Tesla looks forward to continued engagement and actively participating in ongoing discussions. We have a multitude of Australian and international best practice case studies on the ability of grid-forming inverters in providing inertia for system security needs and would welcome the opportunity to have additional discussions to share technical expertise by hosting a workshop with AEMC.

Kind regards,

Tesla Energy Policy Team

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Consultation Questions Response

1. Future credible contingency size in the NEM

Tesla foresees a decline in the NEM contingency size due to the disaggregated nature of IBRs as an energy source. Furthermore, Tesla sees a greater role for distributed energy resources (DER) in the supply mix, further reducing dependencies on a single, large generator. By generating power closer to where it is consumed, such as through rooftop solar, DER decreases the size of the largest contingencies. Paired with energy storage, it balances supply and demand locally, easing grid strain and enabling rapid responses to disturbances, reducing the need for backup reserves. DER-enabled demand response programs also help shift energy use during peak stress periods, while the decentralised nature of DER enhances grid resilience by limiting the impact of potential contingencies.

2. Future estimates of synchronous condensers

The price of synchronous condensers is not expected to decrease significantly. As an established and mature technology, there is limited scope for further cost reductions. In contrast, the cost of Battery Energy Storage Systems (BESS) is anticipated to decline considerably as advancements in energy storage technology and economies of scale reduce prices. This makes BESS an increasingly attractive option for providing grid services, including inertia.

Furthermore, synchronous condensers, like traditional synchronous generators, are susceptible to angle stability issues. These occur when a disturbance (such as a fault or sudden change in demand) causes the rotating elements of the condenser to fall out of sync with the rest of the grid. Maintaining synchronisation across a large network is critical for system stability. Historically, angle stability issues were less of a concern because the grid relied on dispersed, centralised synchronous generators with high inertia and coordinated control. Now, with reduced inertia, clustered synchronous condensers, and a more decentralised grid, these challenges are becoming more pronounced. Also, high penetration of synchronous condensers could introduce small signal stability issues in the NEM. These could be subtle, persistent oscillations in the system that can weaken overall grid stability over time. Such risks should be considered by AEMO and the AEMC when considering the future inertia supply mix.

3. Future role of grid-forming inverters

Tesla has extensively demonstrated the capabilities on the role of GFI in providing inertia, including previous submissions[1][2][3]. As outlined in AEMO's 2023 white paper on the Voluntary Specification for Grid-forming Inverters[4], GFI can set the inertia constant of in a range wider than that of synchronous machines and then can be tuned based on both local and broader network conditions and requirements. Furthermore, AEMO's 2021 white paper Application of Advanced Grid-scale Inverters in the NEM[5]

[1] https://reneweconomy.com.au/world-first-hornsdale-battery-gets-approval-to-deliver-critical-inertia-services-to-grid/
[2] https://www.transgrid.com.au/media/y54k5rp4/2408-tesla-padr-submission.pdf
[3] https://www.aemc.gov.au/sites/default/files/2023-04/AEMC%20Efficient%20Provision%20of%20Inertia%20-%20Tesla%20response__FINAL.pdf
[4] https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf
[5] https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/application-of-advanced-grid-scale-inverters-in-the-nem.pdf

demonstrates that GFI are able to provide the full range of services that synchronous machines can (see figure 1 below).

Figure 1: AEMO 2021 performance comparison of grid-connected generation.

Table 2 Performance comparison of grid-connected generation

Service/capability	Grid-following inverter system	Grid-forming inverter system	Synchronous machines
Can contribute to system strength		✓	✓[A]
Can have positive disturbance withstand (active power oscillation damping)		✓	✓
Can have positive disturbance withstand (fault ride-through capability)	✓	✓	✓
Can contribute to system inertia		✓[B]	✓
Can contribute to FFR	✓	✓	
Can contribute to primary frequency response	✓	✓	✓
Can support a power system island with supply balancing and secondary frequency response	✓	✓	✓
Can initiate or support system restoration	✓[C]	✓	✓

A. Synchronous machines can usually contribute to system strength much more than IBR due to their higher overload capacity.
B. A grid-forming inverter system requires energy storage to deliver inertia. See Section 2.4.
C. Grid-following inverters can support but not initiate system restoration.

GFI provides a more reliable and resilient source of synthetic inertia than synchronous condensers, which rely on mechanical components and can suffer a total loss of inertia if a minor issue forces them offline. In contrast, the modular nature of GFI ensures continued operation even if some battery units experience faults, maintaining inertia provision and fast-frequency response without disruption. Additionally, BESS incorporates predictive maintenance and remote diagnostics, reducing downtime and maintenance costs compared to synchronous condensers, which require physical inspections and mechanical servicing. As the NEM transitions to higher shares of variable renewable energy, the flexibility, scalability, and rapid response of BESS make it a more suitable solution for inertia provision and grid stability.

4. Future inertia supply and costs

Tesla raises concern with the assumptions around the upper bounds of the estimated fixed costs of inertia supply within the HoustonKemp modelling, summarised in figure 2.

Tesla notes that it already has assets that can provide synthetic inertia from IBR and that it has several projects under construction that will be operational before this rule change is completed that will also be able to provide synthetic inertia. Therefore, similarly to existing synchronised generation with $0 fixed costs for inertia supply, existing IBRs should also be considered with a $0 fixed cost column.

Figure 2: Estimated costs of inertia supply

Inertia source		Fixed cost ($/MWs/year)	Variable cost ($/MWs/hour)	Emissions cost ($/MWs/hour)
Synthetic inertia				
Synthetic inertia from IBRs	1hr, 2024	$0 – $806	$0 – $6 (avg: $0.02)	$0
	1hr, 2030	$0 – $488	$0 – $6 (avg: $0.02)	$0

Furthermore, reviewing the key assumptions from the modelling (figure 3), Tesla identifies updated figures around the capital cost for BESS, proposes an alternative to the allocation of a fixed percentage of capital cost dedicated to the purpose of providing inertia, and notes that the BESS inertia constant can be varied across plants for up to 11 seconds.

Figure 3: Assumption for fixed costs of synthetic inertia

Table A2.7: Key parameter assumptions used to estimate upper bound for fixed costs of synthetic inertia

Parameter	Value	Source
Total capital cost of 1 hour BESS	$927,000/MW in 2024 $561,000/MW in 2030 $436,000/MW in 2036	CSIRO 2023/24 GenCost Report, Appx Table B4. (values converted from $/kW to $/MW)
Maximum proportion of capital cost that could be incurred for the purpose of providing inertia (ie, incremental capital cost)	5 per cent	Transgrid has estimated, based on discussions with stakeholders, that the cost of upgrading to a grid-forming inverter may be approximately 5 per cent of BESS capital cost – see: Transgrid, *Meeting system strength requirements in NSW*, *PADR*, June 2024, p 68.
Annual incremental fixed operating and maintenance costs.	1 per cent of incremental capital costs.	HoustonKemp assumption.
BESS inertia constant	6 seconds (ie, for every MW of capacity, the battery can provide 6 MWs of inertia)	AEMC assumption.
BESS asset life	20 years	HoustonKemp assumption.

Tesla challenges the upper bound capital cost estimates for battery storage presented for both 2024 and 2030. The current modelling cites a capital cost of $927,000 per MWh for 2024; however, recent data indicates that actual costs are significantly lower. The CSIRO draft 2024/25 GenCost (noting HoustonKemp use 2023/24 version) report puts the current price of a four-hour battery at $423,000/MWh[6]. This is less than half the price put forward by the modelling for this paper, with RenewEconomy noting that while the CSIRO draft showed plunging battery storage costs, those numbers are likely already out of date[7].

Secondly, Tesla suggests the approach to allocating a 5% proportion of capital cost to be segmented for the proportion of the asset providing inertia, given that this is not reflective of real world plant

[6] https://www.csiro.au/en/research/technology-space/energy/GenCost
[7] Plunging cost of big batteries: Latest gigawatt scale project may set new price benchmark | RenewEconomy

behaviour, as this approach would lead to a material opportunity lost for permanently reserving 5% capacity. An alternative might be to examine how much of an asset's capacity is reserved for inertia provision over its operational lifetime across time intervals and use that to determine an appropriate CAPEX allocation.

Tesla welcomes working with the AEMC and HoustonKemp on data sharing to identify appropriate figures and develop a more robust methodology for determining a capital cost allocation for GFI that aligns with market dynamics and technical realities.

5. Procurement mechanism to meet minimum inertia levels

Tesla supports long-term procurement to remain as the most suitable to meet minimum inertia levels.

6. Other potential benefits from operational procurement

Tesla recommends operational procurement for additional inertia as a real-time inertia market will better provide transparent price signals that incentivize investment in new grid services, ensuring that inertia is procured efficiently and cost-effectively as system needs evolve. Unlike long-term procurement, which locks in suppliers, a dynamic market approach fosters competition, innovation, and investment in new cost-effective sources of inertia as technologies rapidly evolve at a faster rate than procurement rounds through the regulatory processes.

7. Implementation considerations

One of the essential implementation considerations for the procurement of additional inertia is the treatment of inertia from already-synchronised generation. Tesla is strongly aligned with the AEMC's principles of avoiding a wealth transfer from consumers to producers without any improvements in economic efficiency. Therefore, Tesla supports adding eligibility criteria to any operational procurement to ensure that inertia can still be supplied separate from energy.

Tesla recommends further investigation into the distribution of inertia, even in the procurement of 'additional inertia.' While inertia is a system-wide property, real-time transmission constraints may limit the effectiveness of large inertia contributions in certain locations, adding complexity to market design. Ensuring that inertia procurement mechanisms account for these constraints will be critical to maintaining system stability and efficiency.

Other Comments

Market approach for additional inertia

Tesla supports a market-based approach to procuring additional inertia over long-term contracting, as it enhances transparency, efficiency, cost-effectiveness, and technical innovation. Operational procurement allows market dynamics to optimise inertia, energy, and ancillary services in real time, ensuring assets remain available for broader market participation rather than being locked into contracts. This approach is expected to drive competition, lower inertia service costs, and ultimately deliver better outcomes for consumers and overall market efficiency.

Market design feedback

One area for further investigation identified by the AEMC is the modelling for the nonlinear relationship between inertia and FFR in NEMDE. Tesla cautions that linearising the relationship between Fast Frequency Response (FFR) and inertia within NEMDE presents significant challenges. The total system response to a disturbance is not simply the sum of X MW of inertia and Y MW of FFR, as these services interact in complex ways depending on network conditions. Further study is required to determine how best to integrate these dynamics into market design.

While further investigation is required, Tesla proposes potential pathways for exploration to fully replace FFR with an additional inertia market, or to add eligibility for inertia provision as a prerequisite for FFR participation. The WEM in Western Australia provides a useful reference, as AEMO's framework includes a Rate of Change of Frequency (RoCoF) service with a defined speed parameter. While the WEM approach is not directly substitutable, further examination of how both markets define and procure these services may provide insights for an improved NEM design.

While noting the challenges for additional modelling within NEMDE, Tesla encourages further investigation into the costs to AEMO in setting up an inertia market, that "this may significantly increase the costs of this option above the $20 to $50 million level".

Tesla does not support a causer-pays approach in the cost allocation for additional inertia market design and instead supports the AEMC's alternative proposal of smearing costs proportionally across market participants.

Synthetic inertia assumptions

Tesla raises serious concern with embedding dynamic inertia constraints during inertia procurement. If a spot market approach is progressed, it will be critical that the expected response of eligible assets are based on an agreed static configuration and are not expected to be dynamic in response. Under the current Rules, the inertial constant for a grid-forming inverter is agreed upon at the time of connection and is not able to be changed without going through appropriate change processes defined in the Rules (typically the existing 5.3.9 process).

Maintaining static configurations for the inertia constant will resolve the potential challenges outlined in the market design questions around "a partial dispatch of an asynchronous plant may mean it could lower its inertia constant …but could lead to instabilities if inverter settings are improperly tuned and controlled." Tesla strongly advocates for a fixed inertia constant, noting that while the constant itself remains static, the inertial response can still vary based on system needs. This approach ensures stability and mitigates the risk of unintended instabilities arising from dynamic adjustments to inverter settings.

Tesla challenges the assertion that maintaining sufficient headroom or footroom is a key operational uncertainty for effective inertia provision. Unlike frequency response services, inertia is a passive response that does not inherently require active power headroom. Grid-forming BESS can dynamically respond to market conditions and co-optimise across multiple ancillary services in real time. If headroom is required for frequency response services alongside inertia, an operational procurement approach will ensure that assets remain available for full market participation rather than being locked into rigid contractual structures.

Treatment of damping

Tesla would like to briefly draw attention to a slight technical error in the labelling of the diagram below (figure 4). While the diagram itself is an accurate representation of varying levels of inertia, the caption suggests that lower levels of inertia increase the damping requirements, in fact both lines have the same damping requirements. Damping relates to how quickly frequency deviations reduce following a disturbance, with half-life oscillations as the time it takes for the magnitude of a frequency deviation to reduce to half of its initial value. In figure 4, the damping of the higher inertia and lower inertia levels are similar. Lower levels of inertia do not necessarily mean less damping, and rather is site and network specific. Likewise, more inertia does not indicate adequate damping levels – for instance, without power system stabilisers (PSS), heavy synchronous machines with high values of inertia can become unstable.

Figure 4: AEMO Inertia in the NEM Damping Requirements Diagram