Notice of Inertia and Fault Level Shortfalls in Tasmania

November 2019

Important notice

PURPOSE

This report is a notice of AEMO's assessment of an inertia shortfall and a fault level shortfall for the purposes of clauses 5.20B.3(c) and 5.20C.2(c) respectively of the National Electricity Rules. It has been prepared by AEMO using information available at 11 October 2019. Information made available after this date may have been included where practical.

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VERSION CONTROL

Version	Release date	Changes
1.0	13/11/2019	Initial release.

Executive summary

Inertia and system strength are critical requirements for a stable and secure power system.

- A minimum level of inertia is required in the power system to suppress and slow frequency deviations so that automatic controls can respond to sudden changes in the supply–demand balance.
- A minimum level of system strength is also required for the power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance. System strength relates to properties other than inertia, such as voltage, and can also impact on the stability and dynamics of generator control systems. Under the National Electricity Rules (NER), it is measured by fault level at designated fault level nodes.
- Together, the provision of inertia and system strength are required for the robust and secure operation of the power system.

The Tasmania power system is amongst the most advanced systems in the world in relation to its adoption of new technologies, penetration of renewable energy and sophisticated control systems. The system has historically relied on a range of critical system security services being provided by the existing hydro-electric fleet, either as a by-product of their dispatch for energy in the National Electricity Market (NEM), or when the number of synchronous hydro-generator units dispatched by the NEM was low, Hydro Tasmania has voluntarily operated its units in synchronous condenser mode to maintain the minimum level of required services.

As the Tasmanian power system evolves, the outlook for inertia and system strength services in Tasmania is also changing, and during periods of low demand from the grid, combined with high imports from Victoria over Basslink, Tasmania has the potential to experience low levels of synchronous generator unit dispatch. This is expected to occur more often following the commissioning of two large (asynchronous) windfarms over the next 12 months.

As a result, AEMO has assessed that there is an inertia shortfall in Tasmania. In conjunction, AEMO has also reviewed the fault level projections for the Tasmanian region, and AEMO has assessed that there is a fault level shortfall at the fault level nodes of George Town, Burnie, Waddamana and Risdon.

Next Steps

The NER place the responsibility to procure shortfalls in inertia and/or fault level on TasNetworks as the local Transmission Network Service Provider (TNSP), subject to AEMO determining the requirements and declaring a shortfall to be procured, and agreement reached on when these services must be procured by if required within 12 months.

This report constitutes AEMO's notice of these assessments and formal declaration of shortfalls under the National Electricity Rules (NER).

AEMO understands that TasNetworks has proactively sought expressions of interest (EOI) to provide inertia and system strength in Tasmania, in anticipation of AEMO's assessment. AEMO has agreed with TasNetworks that the required services will be made available from 1 April 2020. In the meantime, operational arrangements will continue to be used to securely operate the power system.

AEMO is concurrently continuing its review of requirements for inertia, and three phase fault levels at designated fault level nodes, in Tasmania. Following completion of this review (currently expected before the end of 2019), AEMO may need to issue a further declaration on shortfalls in inertia or system strength.

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1. Background

On 19 September 2017, the Australian Energy Market Commission (AEMC) introduced rule changes in the NER for managing inertia and system strength.[1,2] TNSPs now have the primary responsibility for procuring inertia and system strength services, subject to AEMO declaring a shortfall (this declaration step is a required under the rules to permit the TNSP to procure the services).

In December 2018, AEMO published the 2018 National Transmission Network Development Plan (NTNDP), which included an initial assessment of inertia and system strength across the NEM. At this time, no immediate shortfalls were declared in Tasmania.

As the Tasmanian power system evolves, the outlook for inertia and system strength services in Tasmania is also changing. AEMO has re-assessed that the inertia and fault level projections for the Tasmanian region.

This report constitutes AEMO's notice of these assessments and formal declaration of the following under clause 5.20B.3 and 5.20C.2 of the National Electricity Rules (NER):

- An inertia shortfall in Tasmania[3] - see section 2.
- A fault level shortfall in Tasmania[4] - see section 3.

AEMO has worked closely with TasNetworks in preparing this assessment. TasNetworks has already completed a Request for Expressions of Interest to accelerate the process of obtaining system strength and inertia services as required following completion of this assessment.

Refer to section 4 for more information on the next steps to address these shortfalls.

[1] AEMC. *Completed rule changes: Managing power system fault levels*, available at http://www.aemc.gov.au/Rule-Changes/Managing-powersystem-fault-levels.

[2] AEMC. *Managing the rate of change of power system frequency*, available at https://www.aemc.gov.au/rule-changes/managing-the-rate-of-change-of-power-system-freque.

[3] This document has effect under clause 5.20B.3(c) of the National Electricity Rules (NER) – relating to the formal declaration of a minimum inertia shortfall.

[4] This document has effect under clause 5.20C.2(c) of the National Electricity Rules (NER) – relating to the formal declaration of a fault level shortfall.

2. Inertia

Inertia is a fundamental property of the power system. Sufficient synchronous inertia is required to ensure power system frequency can be maintained within applicable limits under normal conditions and following a system disturbance.

2.1 Background

Synchronous inertia is an inherent property of synchronous generation (e.g. coal, gas, hydro, biomass, geothermal, and solar thermal generation). The inertia of synchronous generators inherently resists changes in frequency, improving the resilience of the power system. Inverter-based resources (such as wind and PV generation) do not currently contribute significant synchronous inertia. As inverter-based (asynchronous) resources displace synchronous generation, the synchronous inertia in the system reduces.

2.2 Inertia Requirements

AEMO is required under the NER to calculate, in accordance with a published methodology[5], and publish, satisfactory and secure requirements for synchronous inertia for each NEM region. The NER also require that AEMO assess and declare a shortfall to enable the TNSP to procure synchronous inertia, and that once declared, the TNSP must procure it by the agreed timing. AEMO is required to operate the power system to meet these requirements using services provided by the local TNSP.

In 2018, AEMO determined the two levels of inertia for each NEM region that must be available for dispatch when a region is at credible risk of being islanded[6]:

- **The Minimum Threshold Level of Inertia** is the minimum level of inertia required to operate an islanded region in a satisfactory operating state. This level is currently 3,200 megawatt-seconds (MW.s) in Tasmania.
- **The Secure Operating Level of Inertia (SOLI)** is the minimum level of inertia required to operate the islanded region in a secure operating state. This level is currently 3,800 MW.s in Tasmania.

Tasmania is connected to the mainland NEM via the Basslink HVDC link. While the Basslink interconnector does provide frequency control, it does not transport synchronous inertia in the same way that an AC link does. Therefore, for the purposes of an inertia assessment under the new rules, Tasmania is treated as a synchronous island.

In projecting an inertia shortfall, AEMO has used a threshold of ensuring the required synchronous inertia is available for 99% of the time – consistent with the approach used for system strength assessments.

2.3 Historical Performance

Historically, the inertia and fault level required to securely operate the Tasmanian power system has been provided from the existing fleet of hydro-electric generators in the state. Either the required inertia was provided as by-product of the dispatch of synchronous hydro-generation in the NEM, or when the number of synchronous hydro-generator units dispatched by the NEM was low, Hydro Tasmania has voluntarily operated its units in synchronous condenser mode to continue to ensure the required services are maintained.

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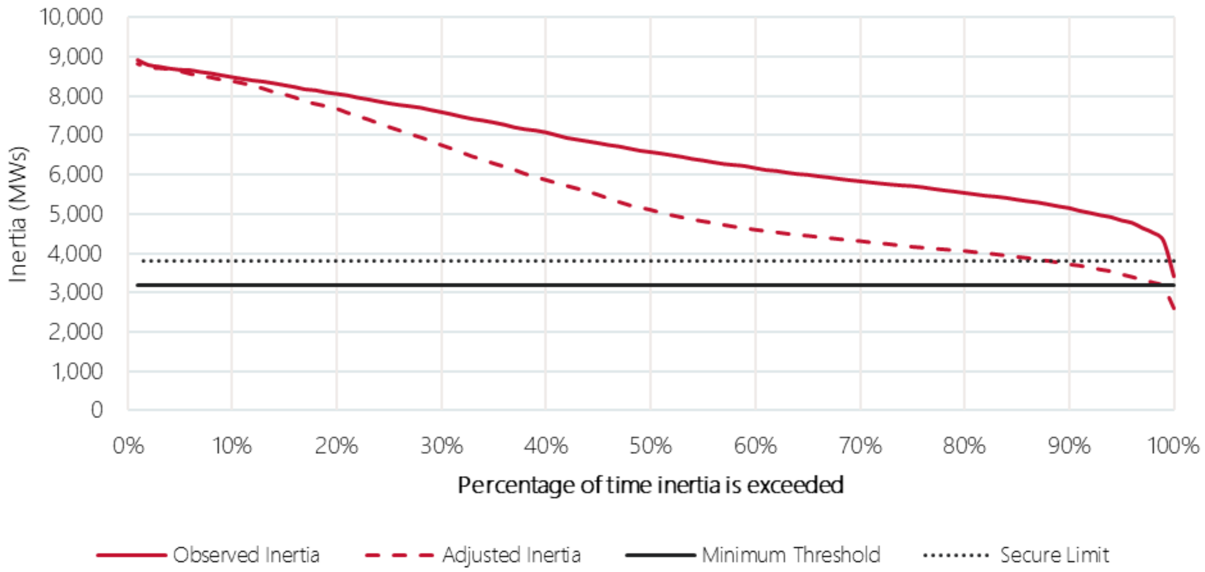
[5]

[6] AEMO. *Inertia Requirements &* Shortfalls, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/Inertia_Requirements_Methodology_PUBLISHED.pdf.

Recent historical inertia outcomes (i.e. 2015-2019) have been reviewed in order to ascertain the expected ranges of inertia. 2015 was a year with conditions where Basslink import was required for a high proportion of the time due to low inflows. For this analysis, historic power system results were adjusted to counteract the impact of Hydro Tasmania running hydro-electric plant in synchronous condenser mode. The results of this analysis are shown in the following figures.

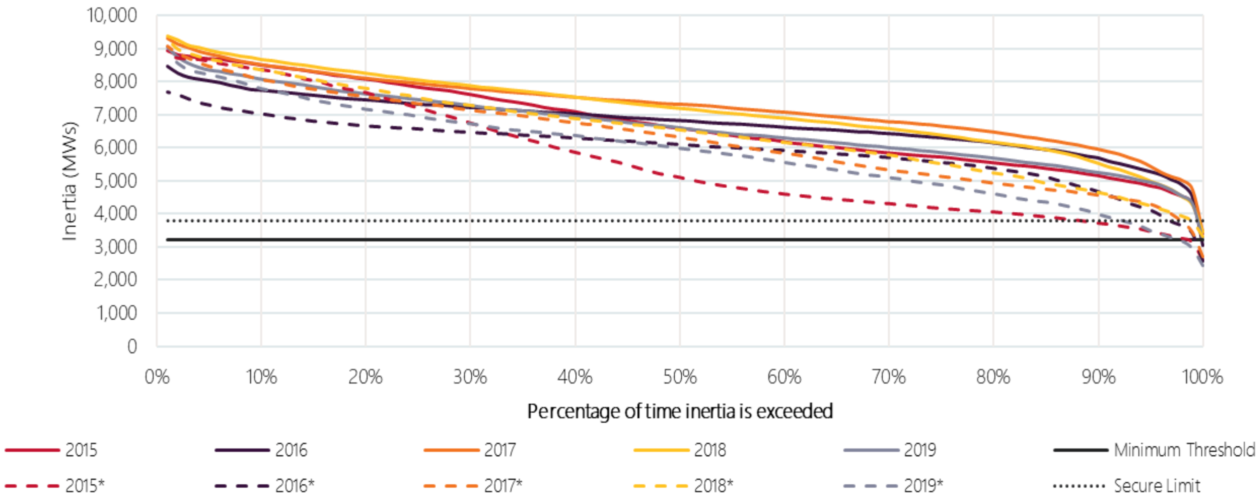
Figure 1 Historical Inertia duration curves (2015) for all Basslink flows, with and without synchronous condenser support



This analysis indicates that, without operating the hydro-generator units in synchronous condenser mode, Tasmanian inertia would have been below the secure level for 12% of the 2015 year. During low inertia periods, hydro-generators operating in synchronous condenser mode provided between 1,400 and 1,500 MW.s of inertia.

The following figure shows historical inertia in Tasmania between 2015 and 2019 calendar years. Similar to the previous analysis, the impact of hydro-electric generators operating in synchronous condenser mode is extracted and shown with dashed lines. This shows that the Tasmanian system has relied on this service between 2% and 12% of the time.

Figure 2 Historical Tasmanian Inertia between 2015 and 2019



* Note that adjusted inertia (offsetting the impact of units run in synchronous condenser mode) is shown with dashed lines.

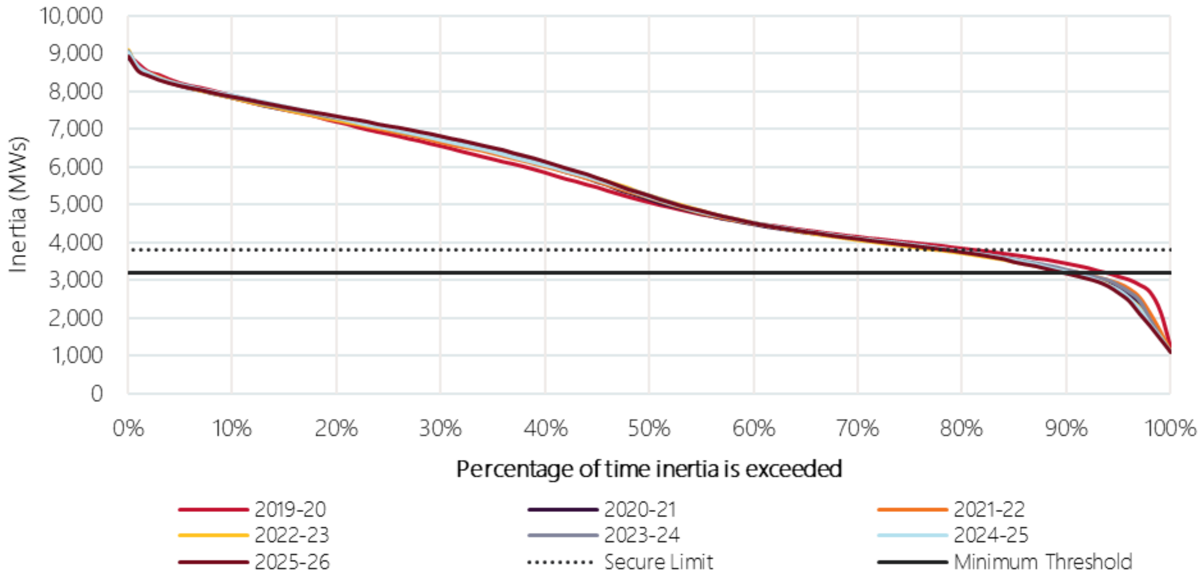
2.4 Projection of inertia levels

The Tasmanian system is evolving, and during periods of low demand from the grid, combined with high imports from Victoria over Basslink, Tasmania has the potential to experience low levels of synchronous generator unit dispatch. This is expected to occur more often following the commissioning of two large (asynchronous) windfarms over the next 12 months.

The recent ISP Insights study has made improvements to how the hydro-generation in Tasmania is modelled – greatly improving the accuracy of inertia projections. Specifically, modelling of the interactions between water catchments and reservoirs now better reflects variations that occur historically. Refer to Appendix A of the ISP Insights paper for more information on hydro-electric modelling improvements[7].

The following figure shows the projected inertia in Tasmania until 2025-26. Without intervention, AEMO projects there will be a shortfall for approximately 20% of the time.

Figure 3 Projected inertia duration curves



The following table outlines the 99th percentile results of this analysis. AEMO will declare an inertia shortfall if the projected inertia is below the requirement for 1% of the time. This table shows the projected annual inertia shortfall.

[7] AEMO. *Building power system resilience with pumped hydro energy storage*, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf.

Table 1 Summary of inertia shortfall assessment

Inertia (MW.s)	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Requirement	3,800	3,800	3,800	3,800	3,800	3,800	3,800
Available 99% of time	2,162	1,529	1,654	1,529	1,491	1,491	1,447
Shortfall	1,638	2,271	2,146	2,271	2,309	2,309	2,353

2.5 Inertia Shortfall

Based on this modelling, AEMO assesses that there is a shortfall currently in synchronous inertia, and this shortfall is projected to reach 2,353 MW.s by 2025-26. An inertia shortfall is expected to materialise in Tasmania during system normal conditions when there are insufficient hydro-generating units online, which can be caused by high levels of import into Tasmania over Basslink combined with low levels of local demand (e.g. public holidays, weekends and overnight periods). The conditions leading to low inertia are expected to increase following the commissioning of Cattle Hill Windfarm (144 MW in Summer 2019-20) and Granville Harbour Windfarm (112 MW in Winter 2020)[8]. This additional 256 MW of wind capacity has the potential to further displace synchronous hydroelectric plant in dispatch, resulting in lower levels of inertia across the network.

AEMO declares an inertia shortfall of 2,350 MW.s in Tasmania.

Ongoing monitoring

AEMO will continue to monitor the inertia requirements in Tasmania, with a specific focus on:

- Commitment status of new generation (e.g. windfarms)
- Changes to rainfall and operation of the hydroelectric fleet
- Generator maintenance requirements and system operability

While these inertia projections do not include contributions from the Tamar Valley Combined Cycle Gas Turbine generator (CCGT)[9], it is noted that this unit is still registered and available for service. The inertia provided by this unit when online will be taken into account operationally, and does not impact on the requirement and timing of the inertia shortfall.

[8] AEMO. *Generator Information Page*, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Generation_Information/August-2019/GenerationInformationPage_20190807.xlsx

[9] The market modelling has assumed no capacity is available from the Tamar Valley combined cycle generating unit, as per the latest advised Generation Information capacities. AEMO. *Generator Information Page*, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Generation_Information/August-2019/GenerationInformationPage_20190807.xlsx

3. System Strength

System strength is a measure of the ability of a power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance. System strength can be considered low in areas with low levels of local synchronous generation and deteriorates further with high penetration of inverter-based resources.

Under the National Electricity Rules (NER), system strength is measured by fault level at designated fault level nodes.

3.1 Background

The increasing integration of inverter-based resources across the NEM has implications for the engineering design of the future transmission system. As clusters of inverter-based resources connect in close proximity, generators will need to offset their impact on system strength and TNSPs will need to ensure a basic level of fault current across their networks.

- **Steady state voltage management** – in systems with low system strength, greater deviations in voltages occur due to disturbances. Larger voltage step changes can occur with the switching in/out of reactive devices which could breach system standards. A lack of reactive capability due to reduced synchronous plant online can lead to difficulty in maintaining secure operating voltages. For example, high voltages can occur during light load periods.
- **Voltage dip** – in a weak network area, voltage dips are deeper, more widespread, and can last longer than in a strong network. For example, the transient voltage dip resulting from a short circuit event will be more severe, more widespread, and slower to recover in a weak system than in a strong system. This condition will generally last until the network fault is cleared by protection systems.
- **Fault ride-through** – the ability of generators to maintain stable operation following a fault is an important aspect of power system security. Inverter-based resources have minimum fault level requirements – if they are not met, then their associated control systems cannot be relied upon to operate in a stable manner. Also, during a network fault, inverter-based resources tend to reduce their active power generation and supply reactive power. In a weak system, where the impact of the network fault is widespread, a large amount of inverter-based resources can enter fault ride-through during the brief period before a fault is isolated, resulting in a power imbalance.
- **Power quality** – for the same consumer demand, voltage harmonics and imbalance are higher in weak systems than in strong systems. This can result in large over-voltages lasting for several seconds, potentially exceeding the withstand capability of local generation. Because synchronous generators dampen harmonics and voltage imbalance, displacement of synchronous generators with inverter-based resources diminishes power quality.
- **Operation of protection** – the trend of decreasing system strength will result in fault current being reduced, which makes it more difficult for protection systems to detect and isolate faults, and can also result in higher likelihood of protection maloperation[10].

3.2 System strength requirements

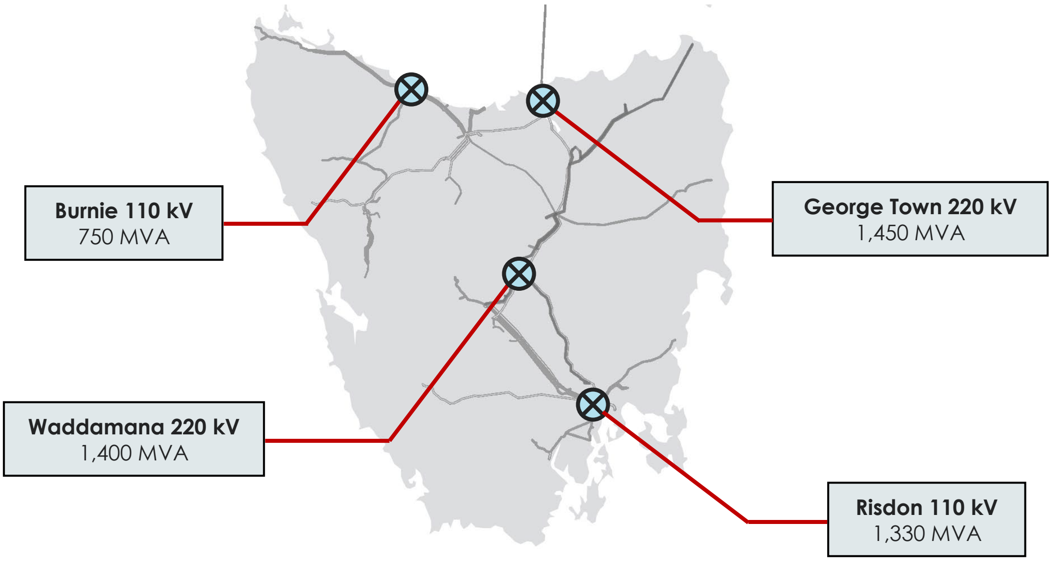
In the NEM, the division of responsibilities for the provision of system strength are as follows:

[10] Protection maloperation can result in additional generation tripping during power system disturbances, loss of load due to maloperation of network equipment, and public safety risks if faults are not cleared.

- AEMO is required to determine the fault level requirements across the NEM in accordance with the System Strength Requirements Methodology[11], and identify whether a fault level shortfall is likely to exist now or in the future.
- A connecting generator is required to implement or fund system strength remediation, such that its connection (or altered connection) does not have an adverse impact on system strength, assessed in accordance with AEMO's system strength impact assessment guidelines.
- The local TNSP is required to provide system strength services to meet the minimum three phase fault levels at relevant fault level nodes if AEMO has declared a shortfall.

AEMO has determined the following system strength requirements for Tasmania.

Figure 4 Tasmanian system strength (fault level) requirements



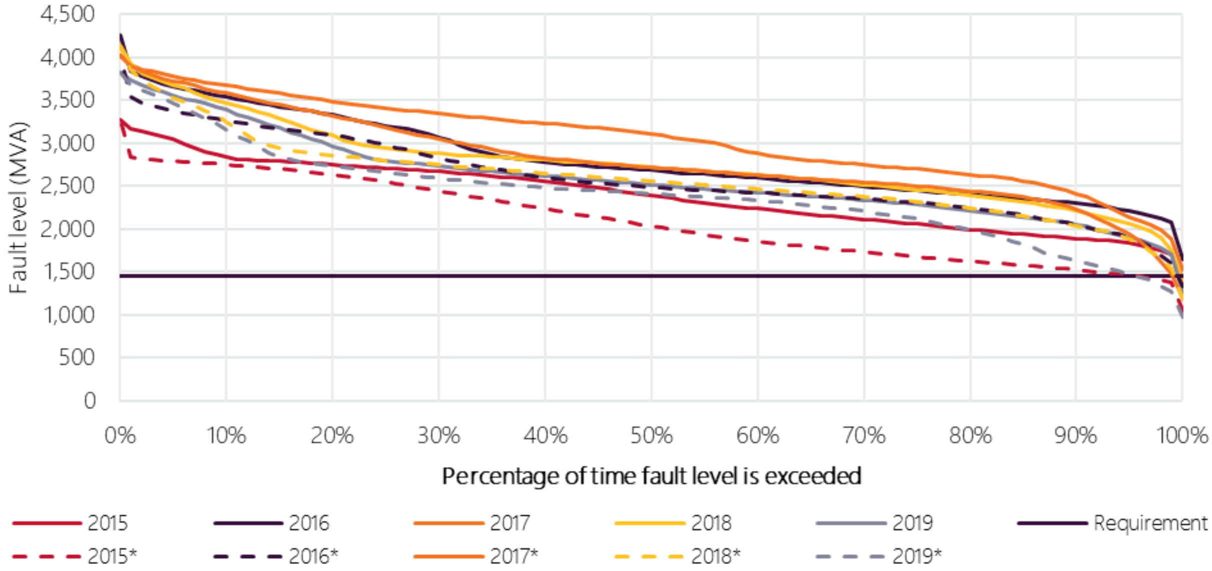
AEMO has undertaken short-circuit analysis based on historical and projected market dispatch for the Tasmanian power system. This short-circuit analysis used the fault level calculation process outlined in the System Strength Requirements Methodology. The outcomes of this analysis are outlined in the following sections.

3.3 Historical performance

Low fault level conditions align with low commitment of synchronous plant in Tasmania. Low synchronous unit commitment can be caused by low demand combined with high import over Basslink. Recent years (i.e. 2015-2019) have been reviewed in order to ascertain the expected range of fault levels. 2015 is a year with conditions where Basslink import was required for a high proportion of the time due to low inflows. The Tamar Valley CCGT was also not in operation in 2015, and this generating unit contributes significantly to fault levels at the George Town 220 kV node. Historic power system results were adjusted to counteract the impact of Hydro Tasmania running hydro-electric plant in synchronous condenser mode. The results of this analysis are shown in the following figures.

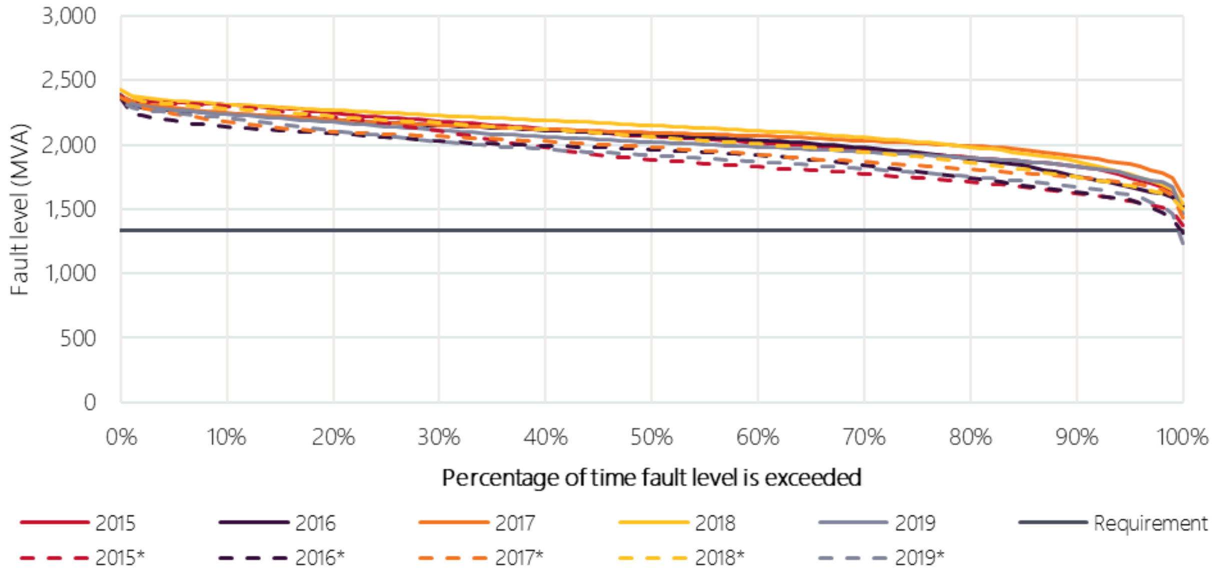
[11] http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Requirements_Methodology_PUBLISHED.pdf

Figure 5 Historical George Town 220 kV fault level duration curves



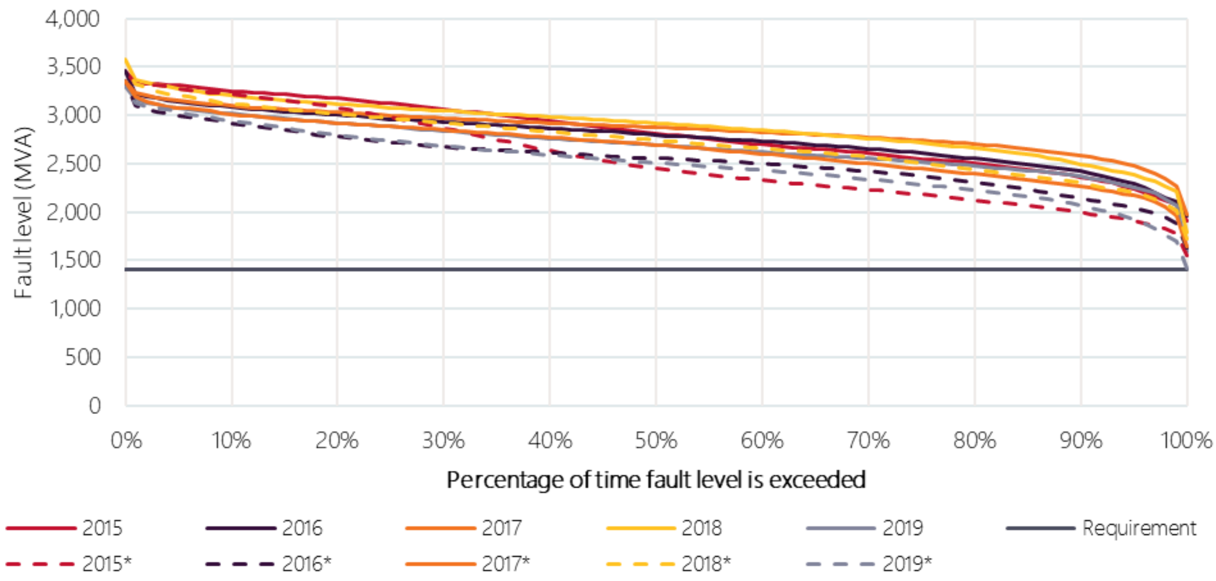
* Note that adjusted fault level (offsetting the impact of units run in synchronous condenser mode) is shown with dashed lines.

Figure 6 Historical Risdon 110 kV fault level duration curves



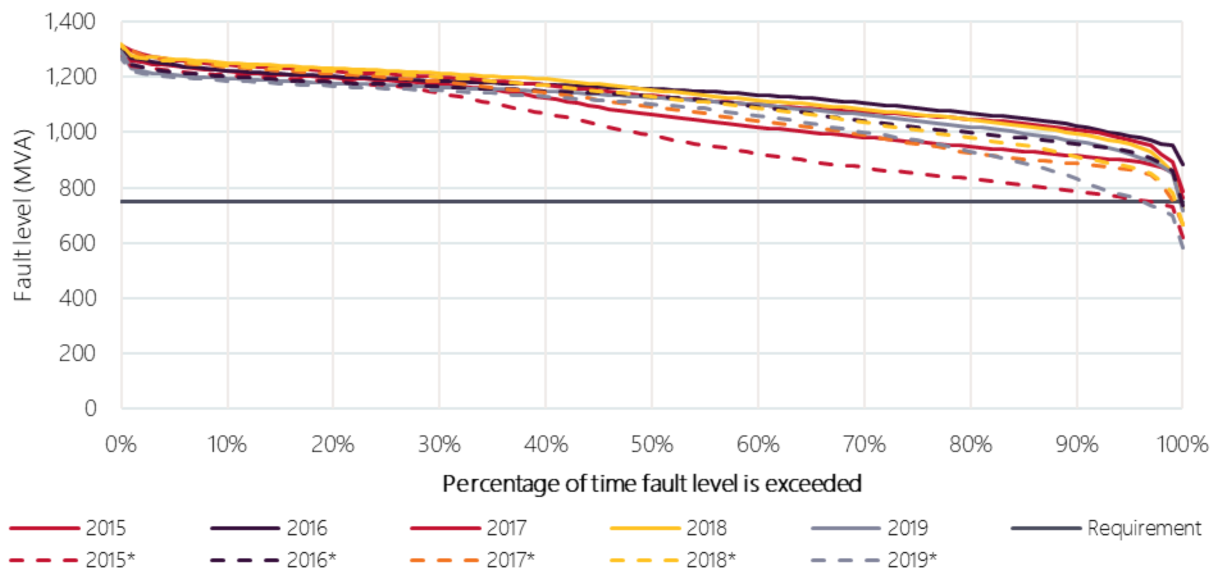
* Note that adjusted fault level (offsetting the impact of units run in synchronous condenser mode) is shown with dashed lines.

Figure 7 Historical Waddamana 220 kV fault level duration curves



* Note that adjusted fault level (offsetting the impact of units run in synchronous condenser mode) is shown with dashed lines.

Figure 8 Historical Burnie 110 kV fault level duration curves



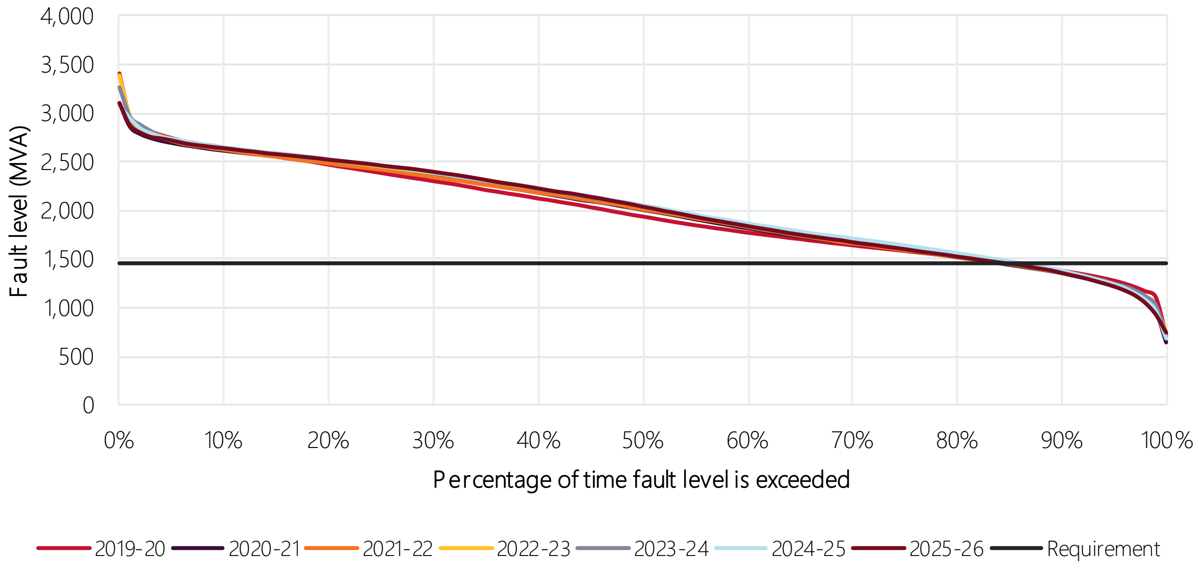
* Note that adjusted fault level (offsetting the impact of units run in synchronous condenser mode) is shown with dashed lines.

This analysis indicates that, without synchronous condenser operation, the George Town 220 kV fault levels would have been below the secure level for 4% of the 2015 year.

3.4 Projection of system strength

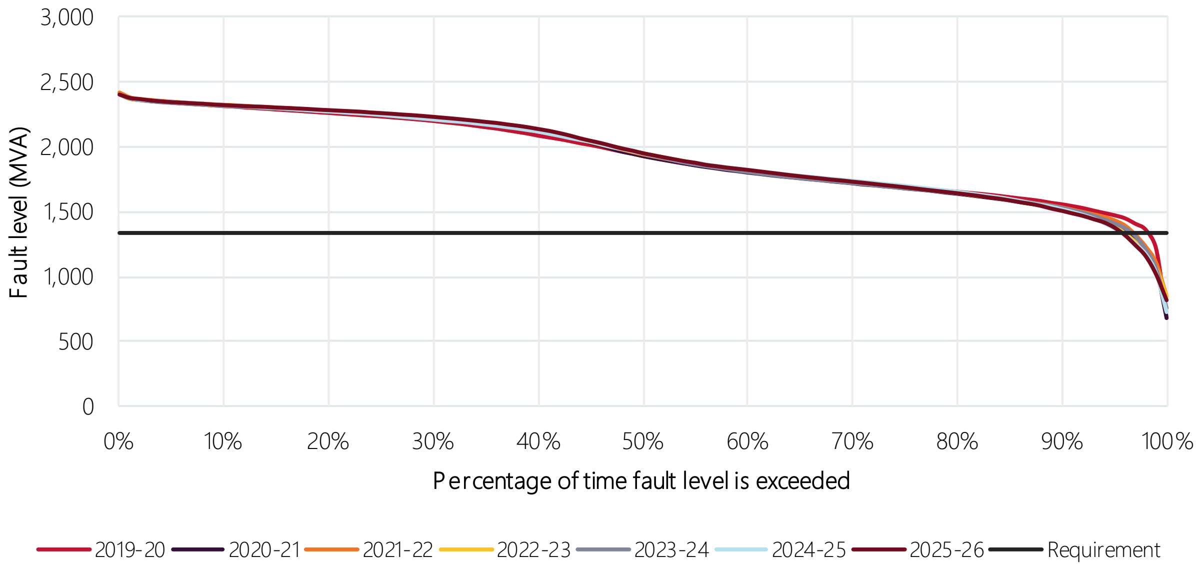
The following figure shows the projected fault level at the George Town fault level node until 2025-26. Sufficient fault level is required at George Town to ensure the stable operation of the Basslink HVDC interconnector. Without action, AEMO projects there could be a fault level shortfall at George Town for approximately 15% of the time.

Figure 9 Projected George Town 220 kV fault level duration curves



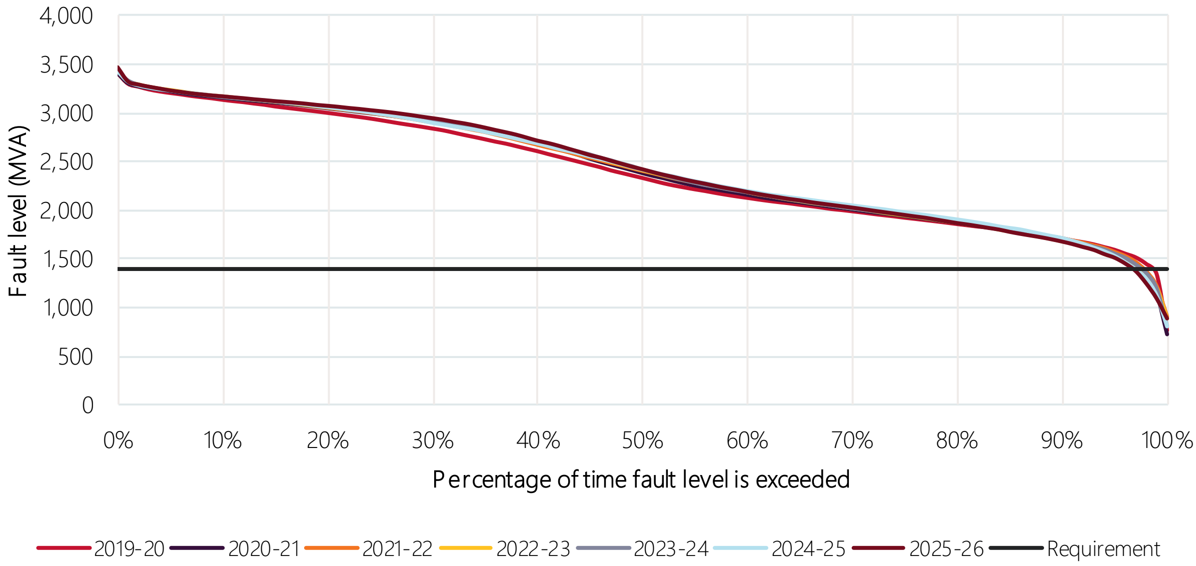
The following figure shows the projected fault level at the Risdon fault level node until 2025-26. Sufficient fault level is required at Risdon to ensure power quality limits, correct operation of protection systems, and so reactive plant can be switched without breaching voltage step change standards. Without action, AEMO projects there could be a fault level shortfall at Risdon for approximately 3% of the time.

Figure 10 Projected Risdon 110 kV fault level duration curves



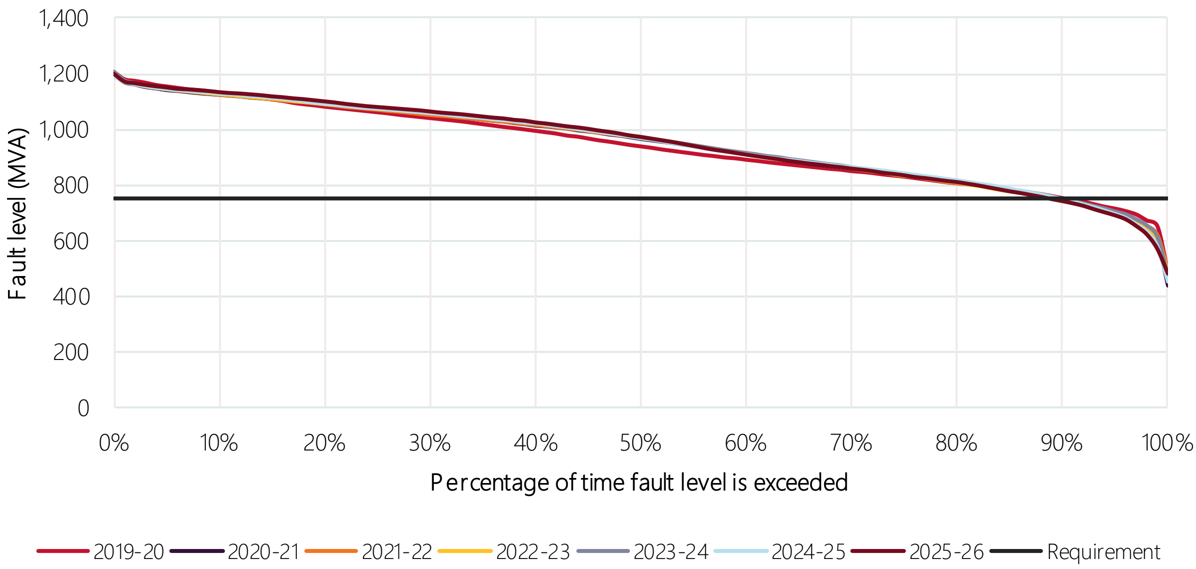
The following figure shows the projected fault level at the Waddamana fault level node until 2025-26. As a synchronous generation centre in Tasmania, sufficient fault level is required at Waddamana to ensure the wider power system can be securely operated. Without action, AEMO projects there could be a fault level shortfall at Waddamana for approximately 3% of the time.

Figure 11 Projected Waddamana 220 kV fault level duration curves



The following figure shows the projected fault level at the Burnie fault level node until 2025-26. As an area electrically remote from sources of synchronous generation, sufficient fault level is required at Burnie to ensure the stability of remote protection systems and inverter-based resources. Without action, AEMO projects there could be a fault level shortfall at Burnie for approximately 10% of the time.

Figure 12 Projected Burnie 110 kV fault level duration curves



The following table shows the projected 99th percentile fault level, the fault level requirement, and the shortfall at each of the four Tasmanian fault level nodes. This demonstrates that there is a fault level shortfall currently at all four of the fault level nodes in Tasmania.

Table 2 Projected fault levels, fault level requirements and fault level shortfalls

Year	George Town			Waddamana			Burnie			Risdon		
	Fault Level	Limit	Shortfall	Fault Level	Limit	Shortfall	Fault Level	Limit	Shortfall	Fault Level	Limit	Shortfall
2019-20	1,116	1,450	334	1,353	1,400	47	651	750	99	1215	1,330	115
2020-21	980	1,450	470	1,155	1,400	245	601	750	149	1062	1,330	268
2021-22	1,026	1,450	424	1,217	1,400	183	620	750	130	1110	1,330	220
2022-23	1,007	1,450	443	1,206	1,400	194	606	750	144	1066	1,330	264
2023-24	1,030	1,450	420	1,203	1,400	197	612	750	138	1066	1,330	264
2024-25	970	1,450	480	1,118	1,400	282	582	750	168	1032	1,330	298
2025-26	924	1,450	526	1,089	1,400	311	571	750	179	1012	1,330	318

3.5 Fault level shortfall

Based on this modelling, AEMO assesses that there are currently conditions where fault level shortfalls may be present at George Town, Risdon, Waddamana and Burnie, and these are expected to increase in incidence and extent over time. A fault level shortfall is expected materialise in Tasmania during system normal conditions when there are insufficient hydro-generating units online, which can be caused by high levels of import into Tasmania over Basslink combined with low levels of local demand (e.g. public holidays, weekends and overnight periods).

Accordingly, AEMO declares a fault level shortfall of:

- 530 MVA at George Town.
- 320 MVA at Risdon.
- 310 MVA at Waddamana.
- 180 MVA at Burnie.

Ongoing monitoring

AEMO will continue to monitor the system strength requirements in Tasmania, with a specific focus on:

- Commitment status of new generation (e.g. windfarms)
- Changes to rainfall and operation of the hydroelectric fleet
- Generator maintenance requirements and system operability

Refer to section 4 for more information on the next steps for addressing this fault level shortfall.

While these fault level projections do not include contributions from the Tamar Valley CCGT[12], it is noted that this unit is still registered and available for service. The fault contributions provided by this unit when online

[12] The market modelling has assumed no capacity is available from the Tamar Valley combined cycle generating unit, as per the latest advised Generation Information capacities. AEMO. *Generator Information Page*, available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Generation_Information/August-2019/GenerationInformationPage_20190807.xlsx

will be taken into account operationally and do not impact on the requirement and timing for addressing the assessed fault level shortfall.

4. Next Steps

This document formally declares shortfalls in Tasmania in inertia (see section 2) and fault level across the four fault level nodes (see section 3).

TasNetworks has proactively sought expressions of interest to provide system strength and inertia services in Tasmania.

Under clause 5.20B.3(c) and 5.20C.2(c)(2), AEMO is required to publish and notify TasNetworks of the date by which inertia or system strength services should be available to meet the relevant shortfall. AEMO and TasNetworks have agreed a date of 1 April 2020.

Updates to operational requirements for the management of inertia and fault levels in the Tasmanian region will then be progressed to enable AEMO to utilise these fault level and inertia services as required. In the meantime, operational arrangements will continue to be used to securely operate the power system.

AEMO is concurrently reviewing the minimum level of inertia, and the requirements for fault level at designated fault level nodes, in Tasmania. Following completion of this review (currently expected before the end of 2019), AEMO may need to update its assessment of the shortfalls in Tasmania.