Notice of Victorian Fault Level shortfall at Red Cliffs

December 2019

Important notice

PURPOSE

This report is a notice of AEMO's assessment of a fault level shortfall at the Red Cliffs fault level node in Victoria for the purposes of clause 5.20C.2(c) of the National Electricity Rules. (NER) It has been prepared by AEMO using information available at 31 October 2019.

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VERSION CONTROL

Version	Release date	Changes
1.0	13/12/2019	Initial release.

Executive summary

System strength is critical requirement for a stable and secure power system. A minimum level of system strength is 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 the power system voltage waveform and can also impact on the stability and dynamics of generator control systems. Under the NER, it is measured by fault level at designated fault level nodes.

The Victorian power system has historically relied on the centralised generation fleet in the Latrobe Valley providing critical system security services, largely as a by-product of their dispatch in the National Electricity Market (NEM) for energy.

As the Victorian power system evolves, with large volumes of inverter-based wind, solar and energy storage resources in remote outer grid areas, the outlook for system strength services at distant nodes like Red Cliffs in north-western Victoria is also changing.

Fault level shortfall at Red Cliffs

As a result, AEMO has re-assessed[1] the system strength projections for the Red Cliffs fault level node and AEMO declares an immediate fault level shortfall of 312 MVA at the Red Cliffs fault level node. The shortfall identified is to address current operational requirements and does not obviate the need for generators to mitigate their impact on reducing system strength.

Next Steps

This report is AEMO's notice of a fault level shortfall assessment for Victoria under the National Electricity Rules (NER).

The NER place the responsibility to procure services to fill the fault level shortfall on the System Strength Service Provider, defined as the Transmission Network Service Provider (TNSP) or jurisdictional planning body for the region. AEMO has this role in Victoria, under its declared network functions.

AEMO will use reasonable endeavours to address the fault level shortfall by 1 January 2021.

[1] The previous fault level requirements for the Red Cliffs fault level node were specified in the System Strength Requirements & Fault Level Shortfalls report, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Requirements_Methodology_PUBLISHED.pdf.

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1. Background

On 19 September 2017, the Australian Energy Market Commission (AEMC) introduced new rules in the NER for managing system strength.[2], Transmission Network Service Providers (TNSPs), as the System Strength Service Providers for each region, are responsible for procuring system strength services to meet a fault level shortfall declared by AEMO. In Victoria, the AEMO is the responsible System Strength Service Provider in its capacity as Victorian TNSP and jurisdictional planning body.

In December 2018, AEMO published the 2018 National Transmission Network Development Plan (NTNDP), which included an initial assessment of system strength across the National Electricity Market (NEM). At that time, no immediate shortfalls were assessed for Victoria.

Evolving power system needs

In the past 12 months, a considerable number of additional inverter-based resources have been connected to and weakly interconnected parts of north-west Victoria and south-west NSW that are very remote from online synchronous machines. Significant additional inverter-based resources are committed to connect in these areas. This trend has necessitated a major uplift in the complex modelling capability necessary to accurately represent power systems with weak grids containing significant inverter-based resources. AEMO continues to build this capability as advances in the modelling technology itself are developed.

AEMO has recently limited the number of inverters able to be online for a number of solar farms in north-west Victoria and south-west NSW to manage identified instabilities post contingent in this area of the network. Considering the remote location from the nearest synchronous generation in the Latrobe Valley or the Snowy Mountains, studies have shown that additional synchronous generation at those centres would not provide any material increase in system strength available in north-west Victoria. As a result, there is no synchronous generation that could be directed to maintain system security by providing additional system strength to this part of the network.

Studies have indicated that local system strength support from synchronous machines in north-west Victoria can significantly increase system strength support allowing an increase in the number of inverters able to be online in this area.

AEMO has completed analysis to identify the amount and location of system strength support to relieve the shortfall that exists currently at the Red Cliffs fault level node in north-west Victoria.

System strength outlook

The outlook for system strength is expected to change as the Victorian power system transforms. This document declares a fault level shortfall at the Red Cliffs fault level node in north-west Victoria based on presently operating and commissioning plant. Additional shortfalls may be declared as AEMO continues to study cases including committed generation. However, AEMO notes that there is limited capacity to provide system strength in this area without significant reinforcement of existing network infrastructure.

The declaration of a fault level shortfall at the Red Cliffs fault level node permits AEMO (as Victorian TNSP) to initiate the required procurement of services to remedy the shortfall.

This document formally declares AEMO's assessment of a fault level shortfall of 312 MVA at the Red Cliffs fault level node in north-west Victoria. AEMO (as System Strength Service Provider for Victoria) will use reasonable endeavours to address this shortfall by 1 January 2021.

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[2] AEMC 2017, Managing power system fault levels, Rule Determination, 19 September 2017, available at https://www.aemc.gov.au/rule-changes/managing-power-system-fault-levels.

2. System Strength Requirements

System strength is the ability of the power system to maintain the voltage waveform at any given location, with and without a disturbance. This includes resisting changes in the magnitude, phase angle, and shape of the voltage waveform.

A strong voltage waveform enables inverter-based resources connected to the 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 available fault current. Presently, areas with increasing volumes of inverter-based generation require more available fault level to enable stable operation to be maintained. It is envisaged that future technology improvements will enhance the inverter-based resources capability in this regard.

2.1 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 proximity, they are now[3] required to remediate their impact on system strength. In addition, TNSPs are required to ensure a basic level of fault current is always available at each fault level node across their networks. This is for the following system security purposes:

- 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.

[3] For projects where the connection application was made on or after 1 July 2018.

- Operation of protection – the trend of decreasing available fault current reduces the ability for protection systems to detect and isolate faults and can increase the likelihood of protection maloperation[4].

2.2 Revised system strength requirements

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

- AEMO is required to determine the system strength requirements at fault level nodes across the NEM and identify whether a shortfall is likely to exist at any node in the future.
- A generator applying to connect or alter its connection after 1 July 2018 is required to implement or fund system strength remediation, if required to ensure 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.[5]
- The regional TNSP responsible for planning and directing augmentation of the electricity transmission network 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.

The System Strength Requirements Methodology published by AEMO on 1 July 2018 determined the system strength requirements for five nodes in Victoria. AEMO has now determined a new fault level requirement of 950 MVA at the Red Cliffs 220 kV fault level node. Other fault level requirements across the NEM, including those presented below, are currently under review.

Table 1 Victorian fault level nodes and minimum fault level

Region	Fault level nodes	Minimum three phase fault level (MVA)
Victoria	Hazelwood 500 kV	8,850
	Dederang 220 kV	3,500
	Thomastown 220 kV	4,100
	Red Cliffs 220 kV	950
	Moorabool 220 kV	4,400

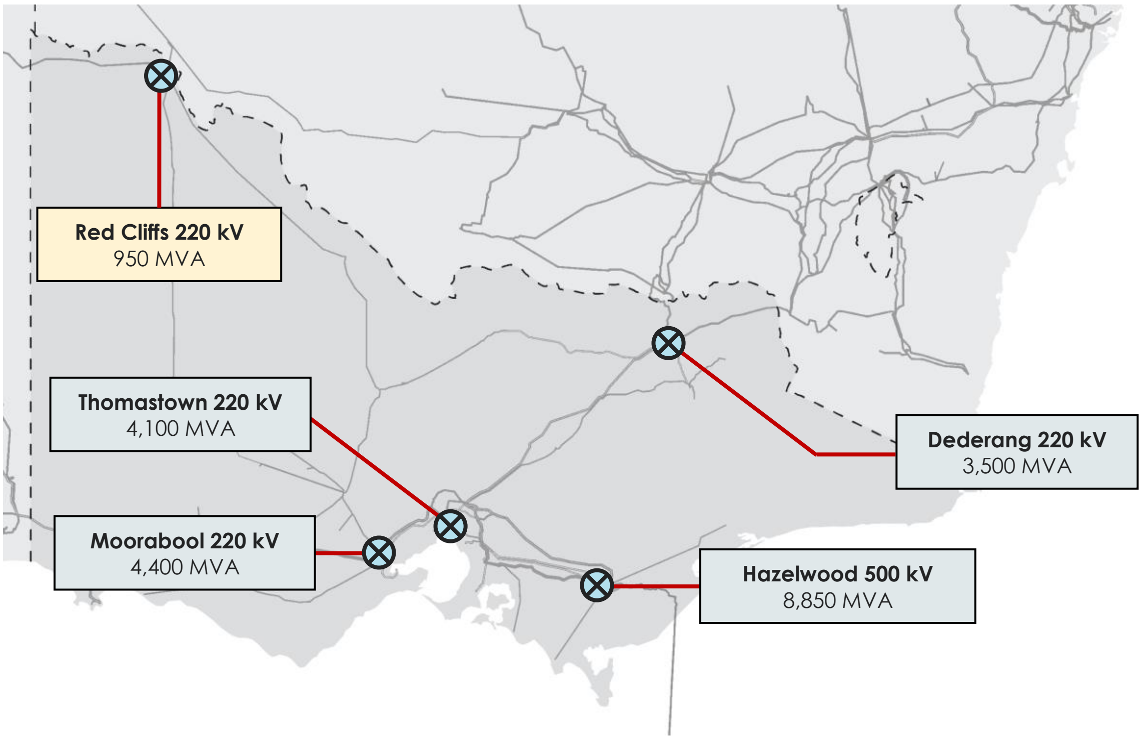
The modelling details and study setup that were used to determine the new fault level requirement at Red Cliffs are outlined in Appendix A1.

The Victorian fault level requirements are shown in the following figure. These requirements, with the exception of Red Cliffs, are currently under review.

[4] 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.

[5] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Impact_Assessment_Guidelines_PUBLISHED.pdf

Figure 1 Victorian fault level requirements

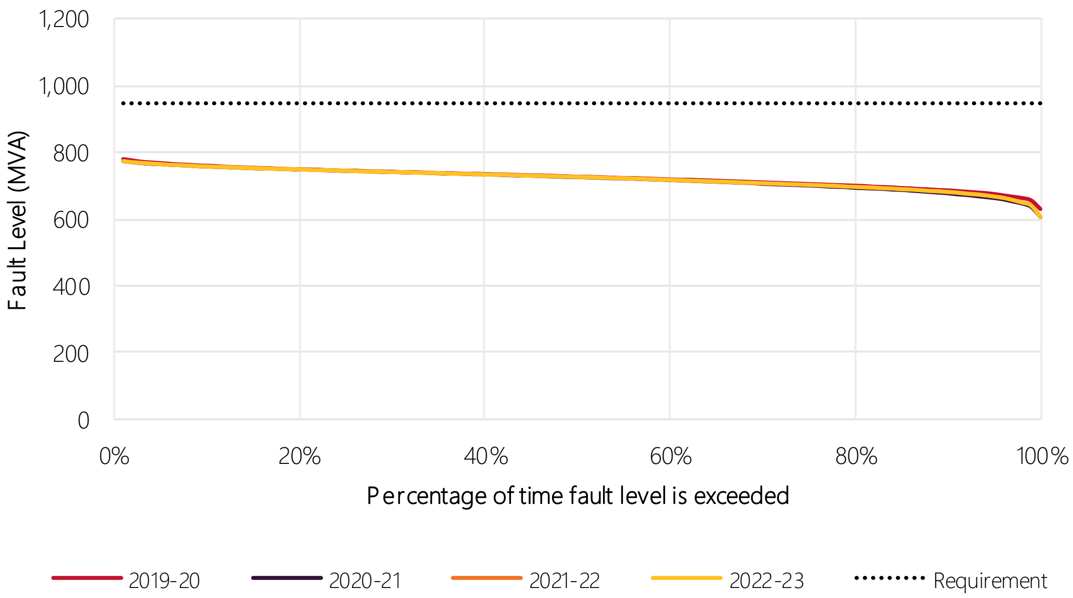


AEMO has performed short-circuit analysis using the fault level calculation process outlined in the System Strength Requirements Methodology. The outcomes of this analysis are outlined in the following section.

3. Projection of System Strength

The following figure shows the projected fault level at the Red Cliffs fault level node until 2022-23. Sufficient fault level is required at Red Cliffs to ensure the stable operation of inverter based resources and correct operation of protection and control systems.

Figure 2 Projected Red Cliffs 220 kV fault level duration curves



AEMO projects there is a fault level shortfall at Red Cliffs for approximately 100% of the time.

The following table shows the projected 99th percentile fault level, the fault level requirement, and the shortfall at the Red Cliffs 220 kV fault level node. This demonstrates that there is a 312 MVA fault level shortfall.

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

Year	Red Cliffs		
	Fault Level	Limit	Shortfall
2019-20	656	950	294
2020-21	638	950	312
2021-22	639	950	311
2022-23	639	950	311

3.1 Fault level shortfall

Based on this modelling, AEMO assesses that there are currently conditions where a fault level shortfall is present at Red Cliffs. Accordingly, AEMO declares a fault level shortfall of 312 MVA at Red Cliffs.

Ongoing monitoring

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

- Commitment status of new generation and storage projects
- Commitment status of network projects (e.g. Project EnergyConnect[6])
- Generator maintenance requirements and system operability

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

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[6] ElectraNet & TransGrid. *Project EnergyConnect*, available at https://www.projectenergyconnect.com.au/.

4. Next Steps

A system strength assessment of north-west Victoria has been carried out using a PSCAD wide area model of Victoria and south-west NSW. Based on the modelling and analysis, and in accordance with AEMO's fault level methodology and shortfall guidelines, AEMO has determined that there is a 312 MVA fault level shortfall at the Red Cliffs fault level node in north-west Victoria.

Fault current is used as a proxy for the level of inertia, fault current, synchronising torque, and other synchronous characteristics which a power system needs – it cannot be used as the only metric for system strength needs. Any new services proposed to provide system strength must be validated through detailed Electromagnetic Transient (EMT) studies.

Date for resolution

Under clause 5.20C.2(c)(2), AEMO is required to publish and notify the date by which the fault level services should be available to meet the relevant shortfall. As there is an existing fault level shortfall at the Red Cliffs node, the date at which fault level services should be available is as soon as practical. AEMO will use reasonable endeavours to address the fault level shortfall by 1 January 2021.

Ongoing monitoring

AEMO will continue to monitor the system strength requirements at the Red Cliffs node in north-west Victoria as models from operating plant are finalised and tuned and models from new intending participants become available. This assessment has been completed with present models available to AEMO and known parameters as of October 2019.

A1. PSCAD modelling and study setup

The Victorian power system model in PSCAD includes detailed models of synchronous generators from major coal and gas fired power stations in Victoria, Murray hydro power stations and AGL hydro power stations near Mount Beauty. Additionally, the model includes asynchronous generators in commercial operation or under commissioning, as of September 2019.

A1.1 Contingencies considered in the studies

The following credible contingencies are considered during this analysis:

- Contingency 1: Two phase to ground fault (2ph-G) and disconnection of Kerang – Bendigo 220 kV line, cleared within primary protection time.
- Contingency 2: Two phase to ground fault (2ph-G) and disconnection of Ararat – Waubra – Ballarat 220 kV line[7], cleared within primary protection time.
- Contingency 3: Two phase to ground fault (2ph-G) and disconnection of Balranald – Darlington Point 220 kV line[8], cleared within primary protection time.

A1.2 Power flow through Murraylink DC interconnector

The Red Cliffs side of Murraylink DC is located within the West Murray zone. Murraylink's runback scheme is considered for all the three evaluated contingencies. Preliminary investigations have shown that a higher Murraylink flow can lead to a more onerous operating condition. Hence, the flow through Murraylink was kept at a maximum, as follows:

- 200 MW from Red Cliffs (VIC) to Berry (SA)

A1.3 Modelling of South Australia power system

South Australia's power system is not modelled for these studies. This is due to several factors regarding the synchronous generators in SA power system:

- They are electrically and geographically distant from Victoria.
- They have less fault current injection compared to Latrobe Valley generation.

Additionally, to increase the computational speed of simulation runs conducted, the SA power system was disconnected from the Victoria power system in the PSCAD model.

A1.4 Success criteria

The success criteria used in the fault level shortfall assessment studies are outlined below.

- Generators, as well as HVDC links (Basslink and Murraylink), remain online.

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[7] This contingency triggers the runback of Ararat WF, Bulgana WF, Crowlands WF, Murra-Warra 1 WF, Waubra WF

[8] This contingency triggers runback of Limondale 2 SF

- All online generators return to steady-state conditions[9] following fault clearance.
- The power system frequency is restored to normal operating frequency band (49.85 Hz – 50.
- Post fault voltage oscillations are adequately damped.

A1.5 Assessment methodology

A1.5.1 Determine minimum synchronous generation

Power system analysis shows that increasing the number of synchronous generators online in the Latrobe Valley has no impact on fault level at the Red Cliffs node. This means that there is no option of directing additional synchronous generation on in Victoria to improve system strength north-west Victoria. To increase fault levels at the Red Cliffs node in the electrically remote north-west Victoria region, local sources of fault current, such as that supplied by synchronous machines (including synchronous condensers) are required.

Synchronous machines support reliable operation of the power system by balancing voltage fluctuations and offering additional fault level capacity. This cannot yet be achieved through currently available inverter-based technologies, including batteries. Synchronous machines have so far been determined to be the most cost-effective source of localised fault current for the purposes of remediating system shortfalls.

To determine the size of the fault level shortfall, different synchronous condenser options were considered in different location in north-west Victoria. As the design, make, size and dynamics of synchronous condensers affects the relative fault level contribution, four representative models were developed and used.[10] Each scenario includes a combination of model, number, and locations of synchronous condensers. The following approach was used to conduct the analysis:

- For each synchronous condenser model, the number of synchronous condensers was increased to north-west Victoria until all plant considered in this study can be operated to meet the success criteria unconstrained.
- Three proposed buses were considered for synchronous condenser installation:
  - Red Cliffs 66 kV bus[11]
  - Kerang 66 kV bus
  - Horsham 66 kV bus.
- For each synchronous condenser scenario, power system responses were assessed against the success criteria in section A1.4.
- Each identified synchronous condenser location was considered in isolation as well in conjunction with other locations to derive the optimal fault level support required.
- After deriving a base line fault level, committed solar farms with synchronous condensers were integrated to identify their impact and check for any adverse interaction with the proposed synchronous condensers. It has been identified that these two new inverter-based (with synchronous condensers) connections along with the proposed synchronous condensers do not adversely impact the outcome of this analysis.

A1.6 Successful synchronous condenser scenarios

Based on the number of iterations with respect of size and location of synchronous condensers, Table 3 provides a summary of the size and location of fault level support that would be required to meet the success

[9] Unless they are tripped as a part of the contingency

[10] Tuning of the AVR and excitation system has not been carried out for specific fault levels

[11] Red Cliffs is a designated Fault Level Node in Victoria

criteria for unconstrained operation of the inverter=based resources in north-west Victoria and south-west NSW.

Table 3 Successful scenarios with synchronous condenser installation

Scenario Number	Syncon Model	Number and location of Synchronous Condensers			Total MVA
		Red Cliffs (Number of synchronous condensers x MVA)	Kerang (Number of synchronous condensers x MVA)	Horsham (Number of synchronous condensers x MVA)	
# 1	Model 1	3 x 26 MVA	3 x 26 MVA	3 x 26 MVA	234
# 2	Model 2	2 x 65 MVA	2 x 65 MVA	2 x 65 MVA	390
# 3	Model 3	1 x 129 MVA	1 x 129 MVA	1 x 129 MVA	387
# 4	Model 4	2 x 60 MVA	2 x 60 MVA	2 x 60 MVA	360

For each scenario three contingencies were tested (as per section A1.1). The successful scenarios indicate that the total minimum required MVA capacity of synchronous condenser installation in north-west Victoria depends heavily on the synchronous condenser model with a range from 234 MVA to 390 MVA.

A1.7 New system strength requirement at Red Cliffs

Based on these studies, and the present fault level observed in the system, AEMO has identified that the fault level requirement at Red Cliffs is 950 MVA.