SHORT-CIRCUIT LEVELS FOR THE VICTORIAN ELECTRICITY TRANSMISSION NETWORK

2015–16 TO 2019–20

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IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information relating to AEMO's planning and development functions for the Victorian electricity transmission network, as at the date of preparation (22 June 2015).

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Australian Energy Market Operator Ltd ABN 94 072 010 327 www.aemo.com.au info@aemo.com.au

NEW SOUTH WALES QUEENSLAND SOUTH AUSTRALIA VICTORIA AUSTRALIAN CAPITAL TERRITORY TASMANIA WESTERN AUSTRALIA

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1. PURPOSE

This report provides maximum short-circuit levels, measured in kilo amperes (kA), for all Victorian electricity transmission Declared Shared Network (DSN) connection points for the five-year outlook period (2015–16 to 2019–20).

Short-circuit levels represent the prospective three phase and single phase-to-ground maximum short-circuit currents that are expected to flow in response to a short-circuit fault at a given point in the power system.

This information is useful for:

- AusNet Services and Victorian Distribution Network Service Providers (DNSPs), to determine equipment specifications in planning and designing their networks.
- Proponents of new generation connections, to better understand emerging DSN connection opportunities and risks.

2. SHORT-CIRCUIT LEVELS APPROACHING SHORT-CIRCUIT LIMITS

The calculated maximum short-circuit levels are compared with short-circuit limit of a bus, which is determined as the lower of:

- Limits from a Use of System Agreement (UoSA), or the National Electricity Rules if not specified in a UoSA.
- The rating of the bus's lowest-rated circuit breaker.

The ratings of terminal station equipment other than circuit breakers have not been considered in determining the short-circuit limit. The ratings contained in this report are based on advice from AusNet Services.

A project has been included in AusNet Service' Network Capability Incentive Parameter Action Plan (NCIPAP) for 2014–17, to assess the existing short-circuit level withstand capability (the short-circuit limits) of the 220kV switchyards at the following terminal stations: Heatherton, Keilor, Moorabool, Rowville, Richmond, Ringwood, Springvale, Thomastown, and West Melbourne. The ratings of 220 kV switchyard equipment, together with the circuit breakers at these terminal stations, will be considered by AEMO in its future annual short-circuit level reviews after the completion of this project in 2016–17.

The following 11 terminal stations have short-circuit levels forecast greater than 95% of the short-circuit limits during the five-year outlook period.

- Brooklyn Terminal Station 66 kV.
- Hazelwood Power Station 220 kV.
- Heatherton 66 kV.
- Jeeralang Terminal Station 220 kV.
- Keilor Terminal Station 66 kV.
- Moorabool Terminal Station 220 kV.
- Red Cliffs Terminal Station 22kV.
- Richmond Terminal Station 220 kV, 66 kV, and 22 kV.
- Templestowe Terminal Station 66 kV.
- Thomastown Terminal Station 66 kV.
- West Melbourne Terminal Station 220 kV and 66 kV.

Changes since the 2014 assessment

New locations that are approaching their short-circuit limits in this year's assessment are:

- Heatherton 66 kV, due to the Heatherton rebuild project which replaces the existing 3 x 220/66 kV transformers with new transformers of lower zero sequence impedances in 2018–19.

AEMO will continue to monitor the above locations to ensure that circuit breaker maximum short-circuit levels remain within the limits set by the National Electricity Rules and the Use of System Agreements (UoSA).

3. SHORT-CIRCUIT LEVEL MITIGATION

Of the 11 locations where short-circuit levels are approaching limits, the following three are forecast to exceed the existing short-circuit limits within the five-year outlook period.

- Hazelwood 220 kV.
- Richmond 220 kV.
- West Melbourne 220 kV.

Options for reducing short-circuit currents in the Victorian electricity transmission network include:

- Operational switching, where selected transmission network circuit breakers may be switched to open, to reduce short-circuit current contributions into critical buses. This is already being undertaken at several locations within the Victorian network, including Hazelwood Power Station 220 kV, Thomastown 220 kV, Rowville 220 kV, Keilor 220 kV, and several 66 kV buses.
- Network reconfiguration such as further bus splits at critical buses or taking circuits out of service during select periods.
- Installing short-circuit current limiting reactors.
- Upgrading the short-circuit current capability of terminal stations by replacing affected plant (such as earth grids, civil structures, circuit breakers, and other switchgear).

Preferred short-circuit level mitigation options are developed on a case-by-case basis, with each project undergoing a comprehensive technical and economic justification.

Specific mitigation measures for each of the locations identified are outlined below:

3.1 Hazelwood Power Station 220 kV

AusNet Services has commenced a staged process to replace aged and limiting circuit breakers at Hazelwood Power Station as part of their asset refurbishment program.

Following completion of the fourth stage, scheduled for 2017, the 220 kV circuit breakers at this station will be fully rated for short-circuit levels up to 40 kA.

AEMO will continue to manage prospective short-circuit levels at Hazelwood Power Station through operational switching arrangements to ensure short-circuit levels remain within circuit breaker ratings.

3.2 Richmond Terminal Station 220 kV

The maximum short-circuit current is expected to exceed the lowest circuit breaker rating of 26.2 kA at Richmond 220 kV. However, only part of this total short-circuit current at the 220 kV bus flows through the limiting circuit breaker.

Based on the short-circuit current expected to flow through individual circuit breakers, AEMO calculates that the short-circuit level could be as high as 29.3 kA for three phase and 28.8 kA for single phase-to-ground faults before the circuit breaker reaches its limit.

Richmond 220 kV short-circuit levels are forecast to remain below 29.3 kA for three phase and 28.8 kA for single phase-to-ground faults, therefore no mitigation measures are required at this stage.

3.3 West Melbourne Terminal Station 220 kV

The maximum short-circuit current is expected to exceed the lowest circuit breaker rating of 26.3 kA at West Melbourne 220 kV, even though only part of this short-circuit current at the 220 kV bus flows through the limiting circuit breaker.

Based on the short-circuit current expected to flow through individual circuit breakers, AEMO calculates that the short-circuit level could be as high as 27.4 kA for single phase-to-ground faults before the circuit breaker reaches its limit. The short-circuit levels exceed this limit in years 2017–18 and 2018–19 by 0.4% and 0.3% respectively.

Although West Melbourne short-circuit levels at the 220 kV bus are forecast to exceed the circuit breaker limit, these short-circuit levels will be controlled to remain within the circuit breaker limits operationally as required.

AusNet Services has advised that there is a committed project to replace the existing four 150 MVA 220/66 kV transformer units with three 225 MVA transformer units by the end of 2021. This project may alleviate potential short-circuit level issues at the West Melbourne Terminal Station.

APPENDIX A. COMMITTED PROJECTS AND CLOSURES

Date	Type	Project
2015–16	Generation	Bald Hills Wind Farm Establishment
	Generation	Anglesea Power Station closure
	Generation	Fisherman's Bend synchronous condenser retirement
	Network	Heywood Terminal Station Third Transformer Installation
	Network	Glenrowan Terminal Station Rebuild
	Network	Rowville Terminal Station Capacitor Installation
	Generation	Portland Wind Farm Establishment
2016–17	Generation	Ararat Wind Farm Establishment
	Network	South Morang Terminal Station Rebuild
2017–18	Network	Ballarat Terminal Station to Moorabool Terminal Station Third Circuit Installation
	Network	Deer Park Terminal Station Establishment
	Network	Brunswick Terminal Station Stage 1 Redevelopment
	Network	Brunswick Terminal Station Stage 2 Redevelopment
	Network	Heatherton Terminal Station Redevelopment
2018–19	Network	Richmond Terminal Station Redevelopment
	Network	Ringwood Terminal Station Rebuild

The 2014 review of short-circuit levels by AEMO did not include the Anglesea Power Station closure, or the Fisherman's Bend synchronous condenser retirement, as these changes occurred after completion of the review. These have been included in this year's assessment.

APPENDIX B. NETWORK MODELLING ASSUMPTIONS

B.1 Network representation

Short-circuit levels in this report are determined based on a network model with all generators, transmission plant, and relevant sub-transmission lines included and in service.

Victoria's neighbouring transmission networks (in New South Wales and South Australia) are represented by simplified equivalent networks that represent the committed generation and transmission projects in those regions.

Generation and transmission plant changes in Tasmania will not affect short-circuit levels in Victoria, as the two regions are connected through a high-voltage direct current (HVDC) link, and as such are not considered in this study.

B.2 Network data

Transmission connection assets, sub-transmission assets, and distribution network embedded generators included in the model are based on information supplied by the distribution businesses and AusNet Services as at 22 June 2015.

B.3 Loads

The total Victorian regional demand is set to the medium scenario, summer 10% probability of exceedance (POE) demand forecasts in the *2015 National Electricity Forecasting Report*.[1]

B.4 Pre-fault voltage profile

The short-circuit currents are proportional to pre-fault voltage, which is reported alongside the short-circuit levels calculated at each location.

B.5 Network switching modes and outage conditions

The transmission network is assumed to be normally operated in one of six switching modes: R0, R1, R2, R5, R5M, and R6. These normal switching modes, detailed in the supporting spreadsheet[2], refer to the arrangement of the Rowville – Ringwood – Templestowe – Thomastown – Keilor 220 kV system for various generation and switching arrangements in Latrobe Valley.

AEMO calculated short-circuit levels under each of these modes, and the highest short-circuit level at each location is presented in this report.

AEMO also assessed short-circuit levels under select outage conditions where automatic control schemes or manual changes in bus configuration are known to result in increased short-circuit levels.

[1] AEMO. *2015 National Electricity Forecasting Report.* Available at: http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report

[2] *AEMO. 2016 VAPR Supporting Material.* Available at: http://www.aemo.com.au/Electricity/Planning/Victorian-Annual-Planning-Report/VAPR-Supporting-Information

B.6 Reactive plant and HVDC

Short-circuit levels presented in this report include contributions from shunt capacitor banks and HVDC interconnectors (Basslink and Murraylink).

The assumptions of reactive plant and HVDC applied in the short-circuit calculation are described in the supporting spreadsheet.[3]

Before calculating the short-circuit levels, static VAR compensators (SVC) are converted from their synchronous condenser model, typically used in steady state assessments, to an equivalent maximum shunt capacitance. This represents the behaviour of an SVC shortly after inception of a short-circuit.

B.7 Network development plan

Committed and proposed changes to network configurations and generation connections to the transmission and distribution networks affect short-circuit levels. The supporting data[4] describes the transmission network developments and committed retirements considered in this short-circuit level assessment.

AEMO is aware of other connection proposals, but these were not sufficiently advanced at the time this report was prepared[5] , so AEMO did not consider them in this report. Such proposals will affect short-circuit levels if they proceed.

Outside Victoria, only new generation developments and retirements in South Australia and New South Wales located near the Victorian border affect Victorian short-circuit levels. AEMO is not aware of any such developments over the five-year outlook period.

[3] Results - Short-Circuit Levels for the Victorian Electricity Transmission Network 2015-16 to 2019-20.xlsx, Reactive Plant & HVDC Control worksheet.

[4] Results - Short-Circuit Levels for the Victorian Electricity Transmission Network 2015-16 to 2019-20.xlsx, Network Development Plan worksheet.

[5] The cut-off date for information was 22 June 2015.

APPENDIX C. SHORT-CIRCUIT LEVEL ASSESSMENTS

AEMO determined the short-circuit levels for three phase and single phase-to-ground faults for the five-year outlook period based on the assumptions described in Appendix B.

The supporting data[6] presents the short-circuit levels and short-circuit limits for each bus under system normal conditions and selected outage conditions.

Short-circuit level information for each bus throughout the five-year outlook period comprises:

- Pre-fault voltage level (kV).
- Three phase-to-ground short-circuit level (3-phase kA) and the related switching mode that delivers the highest short-circuit level.
- Single phase-to-ground short-circuit level (1-phase kA) and the related switching mode that delivers the highest short-circuit level.

The switching modes and outage conditions include:

- Normal switching modes: R0, R1, R2, R5, R5M, and R6.
- Outage conditions, identified by a normal switching mode, then “ID” followed by a number, corresponding to the specific outage condition. For example, R2 ID_6 refers to normal switching mode 2, with outage scenario 6 (Ringwood 66 kV bus tie closed).

Other information is also provided for each bus, comprising:

- Base voltage (kV), which is the nominal bus voltage level.
- Three phase short-circuit limit (3-phase kA) and its basis.
- Single phase-to-ground short-circuit limit (1-phase kA) and its basis.

The basis of a short-circuit limit is either UoSA, NER or CB, due to the limit being determined as the lower of:

- Limits from a Use of System Agreement (UoSA), or the National Electricity Rules (NER) if not specified in a UoSA.
- The rating of the bus’s lowest-rated circuit breaker (CB).

The ratings of terminal station equipment other than circuit breakers were unable to be considered in determining the short-circuit limit in this assessment.

AusNet Services has included a project in its Network Capability Incentive Parameter Action Plan (NCIPAP) for 2014–17, to assess the existing short-circuit level withstand capability (the short-circuit limits) of the 220 kV switchyards at the following terminal stations: Heatherton, Keilor, Moorabool, Rowville, Richmond, Ringwood, Springvale, Thomastown, and West Melbourne. The ratings of other 220 kV switchyard equipment at these terminal stations will be considered by AEMO in its future annual short-circuit level reviews after the completion of this project in 2016–17.

[6] Results - Short-Circuit Levels for the Victorian Electricity Transmission Network 2015-16 to 2019-20.xlsx

MEASURES AND ABBREVIATIONS

Units of measure

Abbreviation	Unit of measure
kA	Kiloamperes
kV	Kilovolts
MVAr	Megavolt-ampere reactive
MVA	Megavolt-ampere

Abbreviations

Abbreviation	Expanded name
AEMO	Australian Energy Market Operator
HVDC	High Voltage Direct Current
NCIPAP	Network Capability Incentive Parameter Action Plan
NER	National Electricity Rules
POE	Probability of Exceedance
SVC	Static VAR Compensator
UoSA	Use of System Agreement

GLOSSARY

Term	Definition
Committed Network Augmentation	Any network project that has advanced to the point where proponents have secured land and planning approvals, entered into contracts for finance and generating equipment, and either started construction or set a firm date.
Phase-to-ground fault	A contingency event where a single phase becomes short-circuited to ground.
Short-circuit level	The current that is expected to flow in response to a short-circuit fault at a given point in the power system. Short-circuit levels are generally measured in kiloamperes (kA).
Three-phase fault	A contingency event where all three phases become short-circuited together.