TRANSFER LIMIT ADVICE - TASMANIA AND SA FCAS

FOR THE NATIONAL ELECTRICITY MARKET

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information about how AEMO calculates contingency frequency control ancillary services requirements in Tasmania and South Australia, as at the date of publication.

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VERSION RELEASE HISTORY

Version number	Release date	Author	Comments
2	1 July 2014	Ben Blake	Added factors for modelling the fast response of Basslink's frequency controller, updated to new AEMO template
1	21 November 2013	Ben Blake	Initial version

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TABLES

FIGURES

1. INTRODUCTION

The Tasmanian and SA (island and at risk of islanding) FCAS requirements are calculated taking into account both the demand and the inertia. The determination of these requirements is complex and requires an iterative calculation process so for Dispatch the contingency FCAS requirements in Tasmania (excluding those for a trip of Basslink or trip of Murraylink) are calculated by an application in AEMO’s energy management system (EMS), called XDFCAS. Pre-dispatch uses an approximation of the calculation done by XDFCAS as XDFCAS only operates in real-time.

For the Basslink trip case, the FCAS requirements also need to include the effect of the frequency control system protection scheme (FCSPS). The impact of the FCSPS creates an FCAS requirement that is highly non-linear over the full range of Basslink flows. Relying on XDFCAS could result in significant over-enablement of FCAS should Basslink flow be dispatched from a low level to a high level of transfer. To avoid this, FCAS requirements are calculated using constraint equations that reflect the non-linear characteristic.

The methodology described below details how the pre-dispatch and Basslink trip constraint equations are formulated.

1.1. Methodology

Due to the complexity of modelling the contingency FCAS requirements calculated by XDFCAS, regression analysis was used to calculate factors on the main inputs to XDFCAS. Using a spread sheet version of XDFCAS the contingency FCAS requirements were calculated for hundreds of cases representing differing demands, inertia, generation or load at risk or interconnector flows. Multiple variable regression analysis was used to calculate the factors on these inputs.

1.2. Conversion to Constraint Equations

This document does not describe how AEMO implements these limit equations as constraint equations in the NEM market systems. This is covered in the Constraint Formulation Guidelines and Constraint Implementation Guidelines.

2. TASMANIA

2.1. Basslink trip for Tasmania to Victoria Transfer

For the trip of Basslink two scenarios are considered. The normal case has Basslink tripping after 400 ms and when at risk of tripping due to lightning the tripping time is set at 650 ms. Changing this value has a significant impact on the regression.

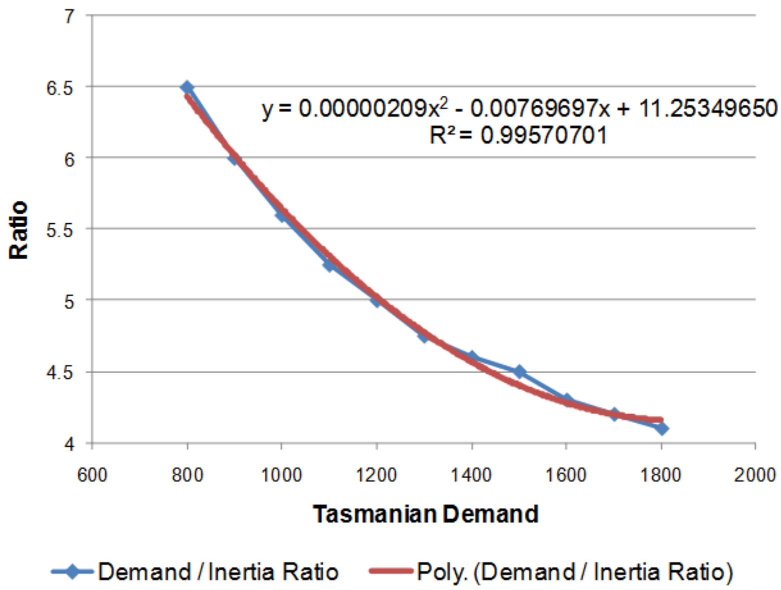
The analysis indicated that the overall FCAS requirements for the 6 and 60 sec services are highly non-linear. For better modelling the regression was separated into 4 segments for 650ms trip time and 2 segments for 400ms trip time. Except for first segment of the Basslink trip case, the data used for each segment was chosen from the range of FCAS requirements which maximised the correlation with the XDFCAS results.

The 5 min services had very little non-linearity so only a single segment was required in both cases.

2.1.1. Effect of the FCSPS

It was observed that when there was sufficient inertia available in Tasmania, the action of the FCSPS for a trip of Basslink gave a linear FCAS requirement. Additionally, the amount of inertia required was dependent on the Tasmanian demand. This was used as the basis for a method of switching between the linear segment and the 3 non-linear segments. The ratio of Tasmanian Inertia / Tasmanian Demand coinciding with the point where the FCAS requirement started becoming non-linear was graphed. From this graph a ratio threshold equation was determined.

Figure 2-1 – Threshold equation for non-linear requirement



From Figure 2-1 the ratio threshold equation is:

Ratio Threshold = 0.00000209 * Tasmanian Demand2

- 0.00769 * Tasmanian Demand

+ 11.253

2.1.2. System Normal

The following cases consider Basslink tripping in 400 ms.

Table 2-1 – Tasmania Raise 6 second coefficients for trip of Basslink

Term	Segment 1	Segment 2
Intercept	-11.728	-30.807
Tasmanian Inertia	-0.0012	-0.0432
Basslink (Tas to Vic)	-0.0399	-0.267
Tasmanian Demand	0.0541	0.15

Table 2-2 – Tasmania Raise 60 second coefficients for trip of Basslink

Term	Segment 1	Segment 2
Intercept	-15.504	-25.7
Tasmanian Inertia	-0.00112	-0.0436
Basslink (Tas to Vic)	-0.046	-0.266
Tasmanian Demand	0.0665	0.175

Table 2-3 – Tasmania Raise 5 minute coefficients for trip of Basslink

Term	Segment 1
Intercept	-13.898
Tasmanian Inertia	0.00046
Basslink (Tas to Vic)	-0.0013
Tasmanian Demand	0.0928

2.1.3. Basslink tripping time of 650 ms

The following section details the case when Basslink is at risk of tripping due to lightning and the Basslink tripping time is 650 ms. The range of data used for the Raise 6 second regression was for XDFCAS requirements less than 150 MW (2nd equation, 150 MW to 225 MW (3rd equation) and > 225 MW for the 4th equation.

Figure 2-2 – Raise 6 second requirement for Tasmanian demand of 1600 MW and inertia = 5000 MWs

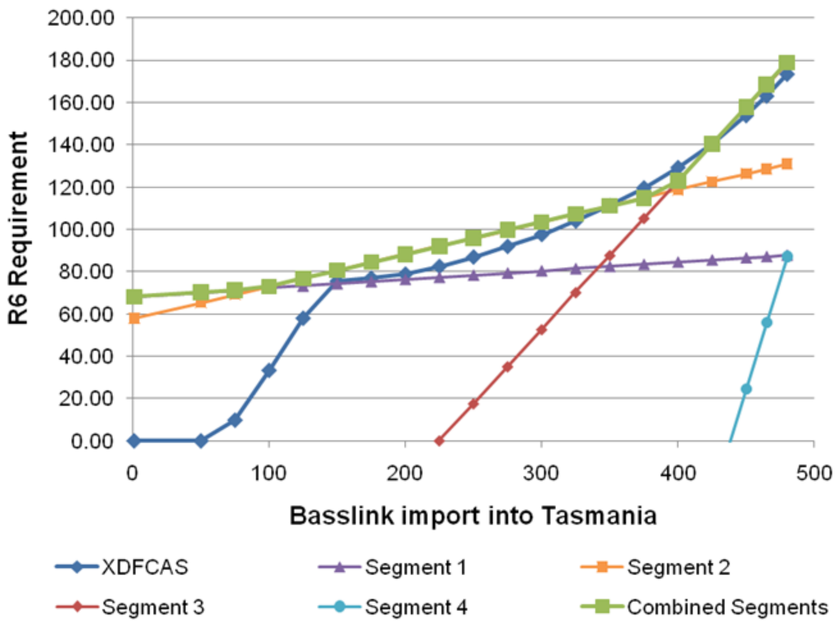


Table 2-4 – Tasmania Raise 6 second coefficients for trip of Basslink (650 ms)

Term	Segment 1	Segment 2	Segment 3	Segment 4
Intercept	-11.947	2.908	33.893	100.355
Tasmanian Inertia	-0.00102	-0.0142	-0.0775	-0.252
Basslink (Tas to Vic)	-0.0408	-0.152	-0.7	-2.08
Tasmanian Demand	0.0532	0.0787	0.122	0.157
Ratio Threshold Swamp		Yes	Yes	Yes

The range of data used for the Raise 60 second regression was for XDFCAS requirements less than 150 MW (2nd equation, 150 MW to 275 MW (3rd equation) and > 275 MW for the 4th equation.

Figure 2-3 – Raise 60 second requirement for Tasmanian demand of 1600 MW and inertia = 5000 MWs

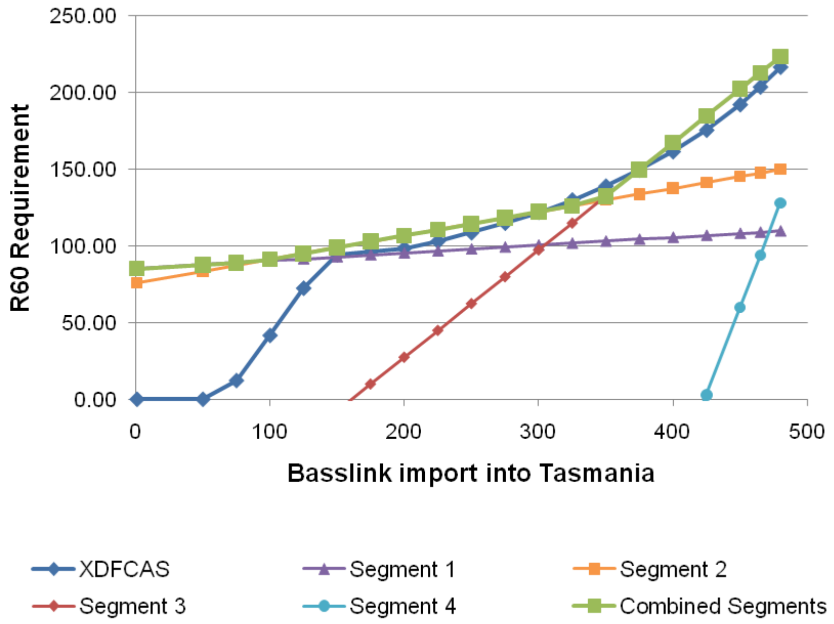


Table 2-5 – Tasmania Raise 60 second coefficients for trip of Basslink (650 ms)

Term	Segment 1	Segment 2	Segment 3	Segment 4
Intercept	-14.934	1.046	32.21	197.824
Tasmanian Inertia	-0.00128	-0.0129	-0.0772	-0.285
Basslink (Tas to Vic)	-0.051	-0.154	-0.7	-2.27
Tasmanian Demand	0.0665	0.088	0.151	0.165
Ratio Threshold Swamp		Yes	Yes	Yes

Figure 2-4 – Raise 5 minute requirement for Tasmanian demand of 1600 MW and inertia = 5000 MWs

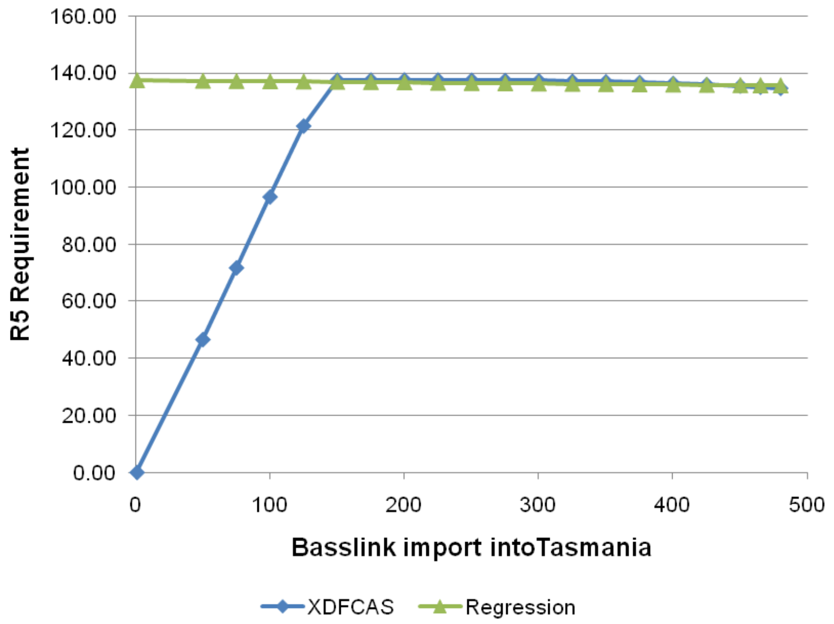


Table 2-6 – Tasmania Raise 5 minute coefficients for trip of Basslink (650 ms)

Term	Segment 1
Intercept	-13.898
Tasmanian Inertia	0.00046
Basslink (Tas to Vic)	-0.0013
Tasmanian Demand	0.0928

2.2. Tasmanian Generator Trip

The following factors were generated (for the trip of a single large generator or multiple generators) using the same methodology as outlined in section 1.1. The inertia used in each case is the total inertia in Tasmania less the inertia being supplied by the contingent units.

Note: Due to the highly non-linear nature of the FCAS requirements in Tasmania, the maximum generation at risk is to be capped at 250 MW. This is pending further studies to determine the veracity of the XDFCAS calculations and other possible effects on the power system.

2.2.1. Basslink able to transfer FCAS

The following factors are to be used in the case when Basslink is able to transfer FCAS. These take into account the fast response of Basslink's frequency controller[1]. The frequency level used for the 60 second service is 0.01 Hz different to the 6 second service.

Table 2-7 – Raise coefficients for a Tasmanian generator trip – Basslink able to transfer FCAS

Term	R6 Factors	R60 Factors	R5 Factors
Intercept	30.2822	-18.0862	0.6678
Basslink headroom	-1.4479	-0.6915	-1.0122
Musselroe MW	0.0341	-0.0242	0.0008
Bluff Point MW	0.0154	-0.0115	0.0004
Studland Bay MW	0.0283	-0.0200	0.0007
Tas MW at risk	1.3759	0.7967	1.0083
Tasmanian Demand	-0.0490	-0.0262	-0.0037
Tasmanian Inertia - Contingency	-0.008811	0.002653	0.000250

2.2.2. Basslink unable to transfer FCAS

In dispatch when Basslink is unable to transfer FCAS the requirements for Tasmanian generator trip(s) use the real-time FCAS requirements calculator – XDFCAS. The following factors are used in Pre-dispatch. The maximum of the 4 equations is to be implemented as the pre-dispatch RHS.

[1] AEMO, *FCAS calculation changes in Tasmania*, Available at: http://www.aemo.com.au/Electricity/Market-Operations/Congestion-Information-Resource/FCAS-calculations-changes-in-Tasmania. Viewed on 30 June 2014.

Figure 2-5 – Raise 6 second requirement for Tasmanian demand of 1600 MW and inertia = 6500 MWs

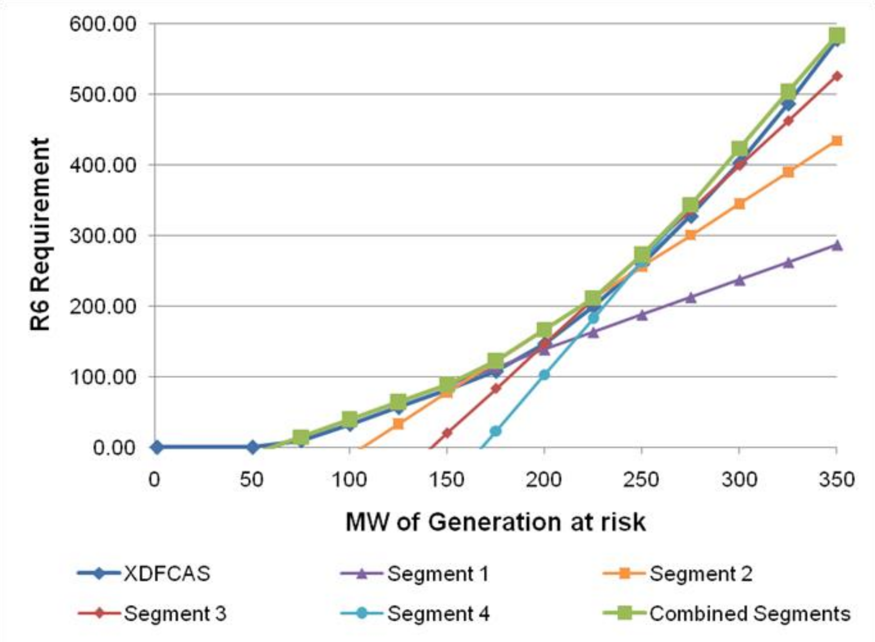


Table 2-8 – Raise 6 second coefficients for a Tasmanian generator trip – Basslink unable to transfer FCAS

Term	Segment 1	Segment 2	Segment 3	Segment 4
Intercept	8.15916	50.28354	40.9621	54.19972
Tasmanian Inertia - Contingency	-0.0024	-0.02375	-0.04297	-0.06793
Tas MW at risk	0.99135	1.78517	2.5304	3.20369
Tasmanian Demand	-0.03288	-0.05393	-0.07596	-0.09399

Figure 2-6 – Raise 60 second requirement for Tasmanian demand of 1600 MW and inertia = 6500 MWs

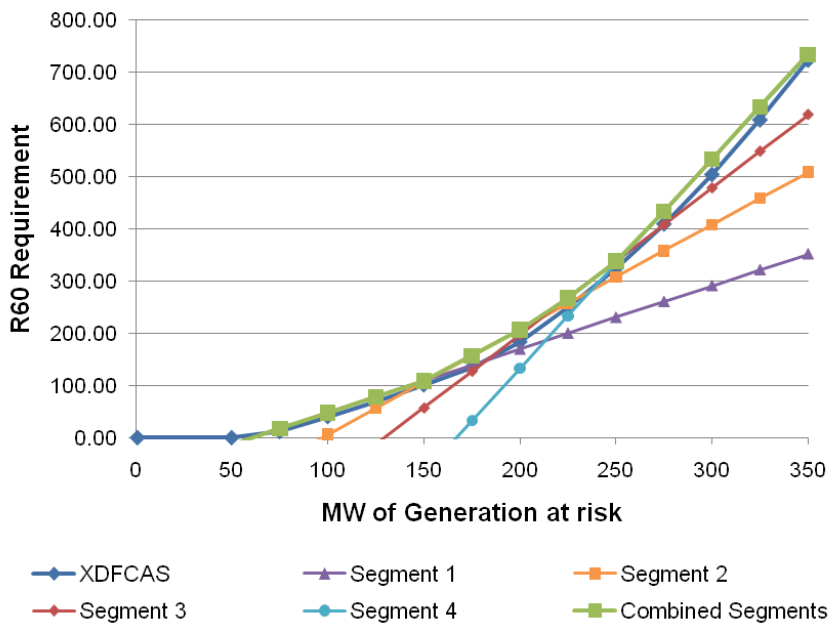


Table 2-9 – Raise 60 second coefficients for a Tasmanian generator trip – Basslink unable to transfer FCAS

Term	Segment 1	Segment 2	Segment 3	Segment 4
Intercept	7.49543	57.31124	58.99631	60.59392
Tasmanian Inertia - Contingency	-0.00249	-0.02452	-0.04429	-0.08397
Tas MW at risk	1.21537	2.01016	2.80255	4.00339
Tasmanian Demand	-0.04043	-0.05786	-0.08347	-0.1139

Figure 2-7 – Raise 5 minute requirement for Tasmanian demand of 1600 MW and inertia = 6500 MWs

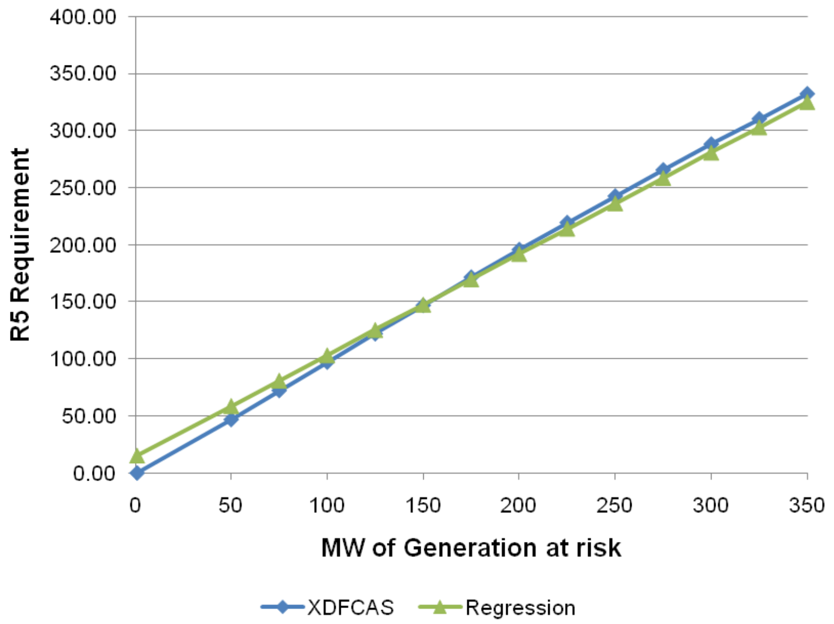


Table 2-10 – Raise 5 minute coefficients for a Tasmanian generator trip – Basslink unable to transfer FCAS

Term	Segment 1
Intercept	-11.2192
Tasmanian Inertia - Contingency	0.00138
Tas MW at risk	0.88728
Tasmanian Demand	0.01041

2.3. Tasmanian Load Trip

The following factors were generated (for the trip of a single large load and multiple loads) using the same methodology as outlined in 1.1.

2.3.1. Basslink able to transfer FCAS

The following factors are to be used in the case when Basslink is able to transfer FCAS. These take into account the fast response of Basslink's frequency controller. The frequency level used for the 60 second service is 0.01 Hz different to the 6 second service.

Table 2-11 – Lower coefficients for a Tasmanian generator trip – Basslink able to transfer FCAS

Term	L6 Factors	L60 Factors	L5 Factors
Intercept	11.3686	-2.1591	-0.2984
Basslink headroom	-1.4431	-0.9198	-1.0059
Tas MW at risk	1.3594	0.9351	1.0074
Tas Demand	-0.0467	-0.0371	-0.0031
Tas Inertia	-0.005272	0.000636	0.000235

2.3.2. Basslink unable to transfer FCAS

In dispatch when Basslink is unable to transfer FCAS the requirements for Tasmanian load trip(s) is to use the XDFCAS. The following factors are used in pre-dispatch. The maximum of the 4 equations is to be implemented as the pre-dispatch RHS.

Figure 2-8 – Lower 6 second requirement for Tasmanian demand of 1600 MW and inertia = 6500 MWs

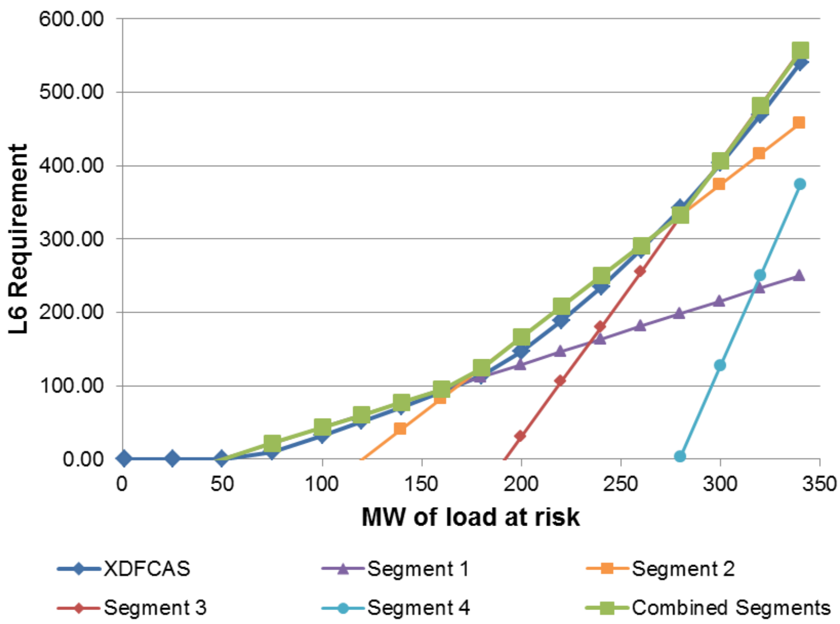


Table 2-12 – Lower 6 second coefficients for a Tasmanian generator trip – Basslink unable to transfer FCAS

Term	Segment 1	Segment 2	Segment 3	Segment 4
Intercept	9.76	42.063	13.41	-98.697
Tasmanian Inertia - Contingency	-0.001396	-0.029565	-0.085366	-0.206736
Tas MW at risk	0.86338	2.09199	3.75816	6.1941
Tasmanian Demand	-0.02747	-0.06402	-0.11222	-0.18064

Figure 2-9 – Lower 60 second requirement for Tasmanian demand of 1600 MW and inertia = 6500 MWs

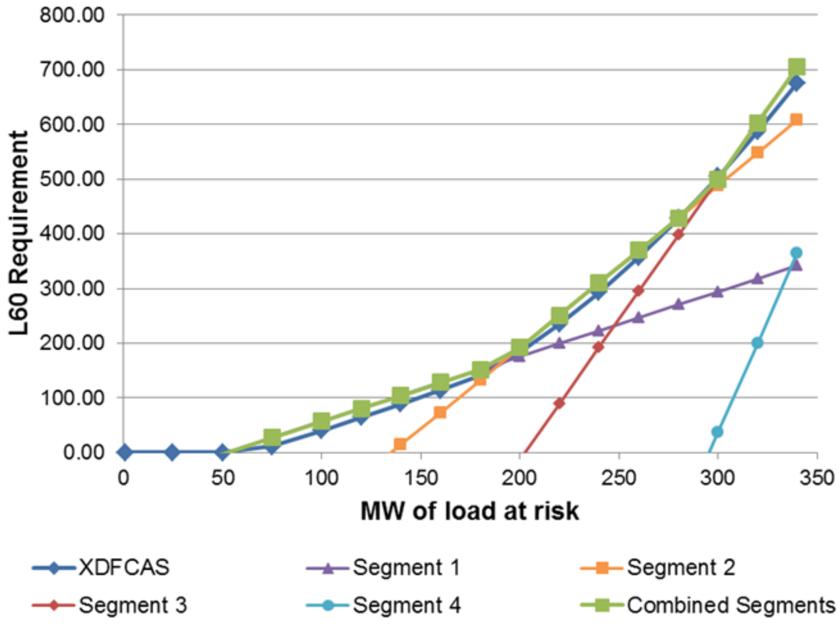


Table 2-13 – Lower 60 second coefficients for a Tasmanian generator trip – Basslink unable to transfer FCAS

Term	Segment 1	Segment 2	Segment 3	Segment 4
Intercept	20.732	41.723	-30.491	-113.599
Tasmanian Inertia - Contingency	-0.003455	-0.029565	-0.117806	-0.296289
Tas MW at risk	1.18623	2.96564	5.12839	8.19264
Tasmanian Demand	-0.03746	-0.08766	-0.1514	-0.23869

Figure 2-10 – Lower 5 minute requirement for Tasmanian demand of 1600 MW and inertia = 6500 MWs

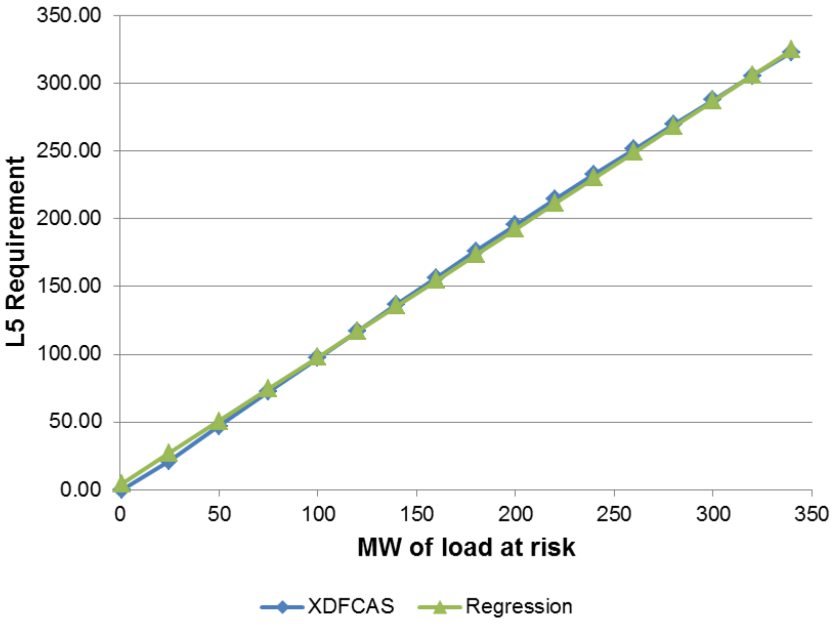


Table 2-14 – Lower 5 minute coefficients for a Tasmanian generator trip – Basslink unable to transfer FCAS

Term	Segment 1
Intercept	-7.68
Tasmanian Inertia - Contingency	0.0010471
Tas MW at risk	0.94558
Tasmanian Demand	0.00271

3. SOUTH AUSTRALIA

3.1. South Australia Island Generator Trip

The following limit equations are to be used when South Australia is an island for loss of the largest generating unit or for the network event connecting a group of generators (such as Lake Bonney 1, 2 and 3). They can also be used for loss of Murraylink for Vic to SA transfers.

Figure 3-1 – Raise 6 second requirement for South Australian demand of 1600 MW and inertia = 6500 MWs

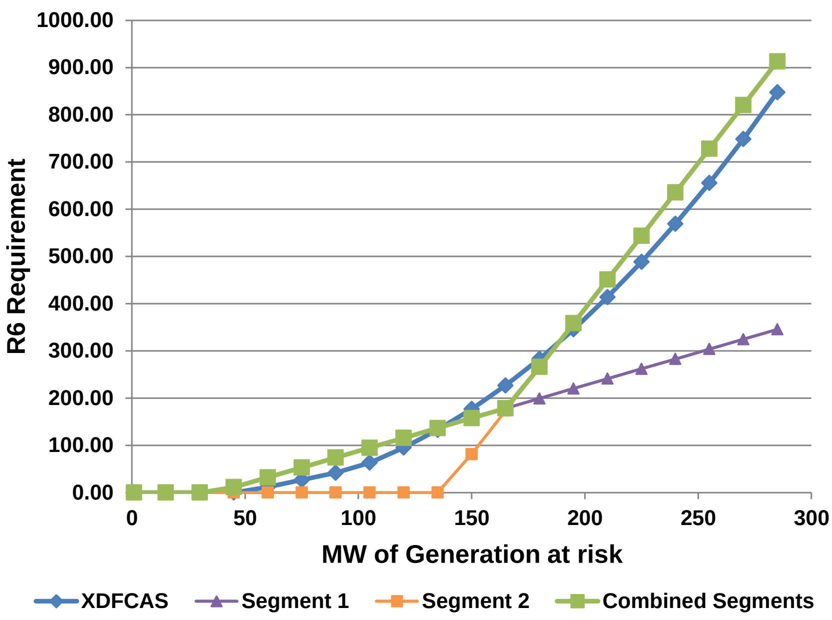


Table 3-1 – South Australia Raise 6 second coefficients for a generator trip

Term	Segment 1	Segment 2
Intercept	43.054	-174.5728
SA Demand	-0.0373	-0.1447
SA Inertia	-0.005355	-0.067216
SA MW at Risk	1.3928	6.1619

Figure 3-2 – Raise 60 second requirement for South Australian demand of 1600 MW and inertia = 6500 MWs

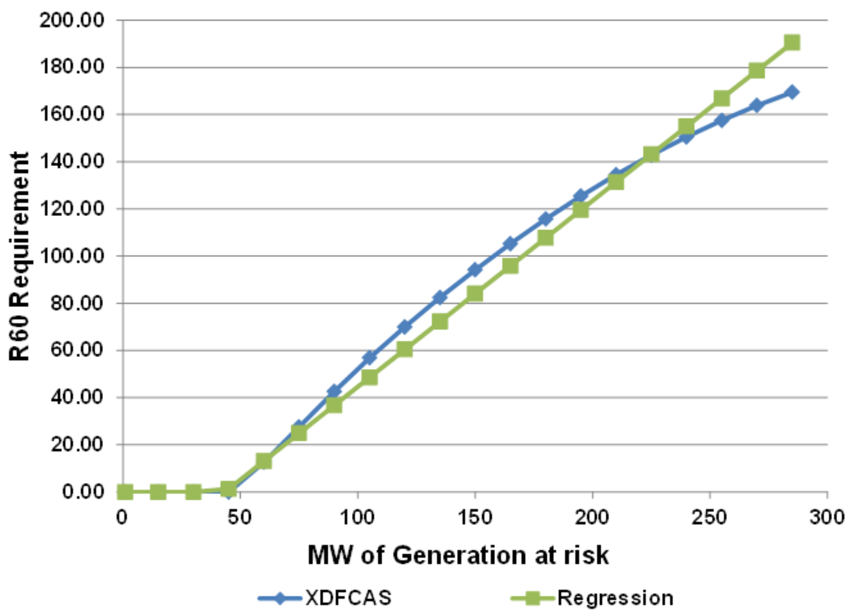


Table 3-2 – South Australia Raise 60 second coefficients for a generator trip

Term	Segment 1
Intercept	-11.2844
SA Demand	-0.0211
SA Inertia	0.001679
SA MW at Risk	0.7883

Figure 3-3 – Raise 5 minute requirement for South Australian demand of 1600 MW and inertia = 6500 MWs

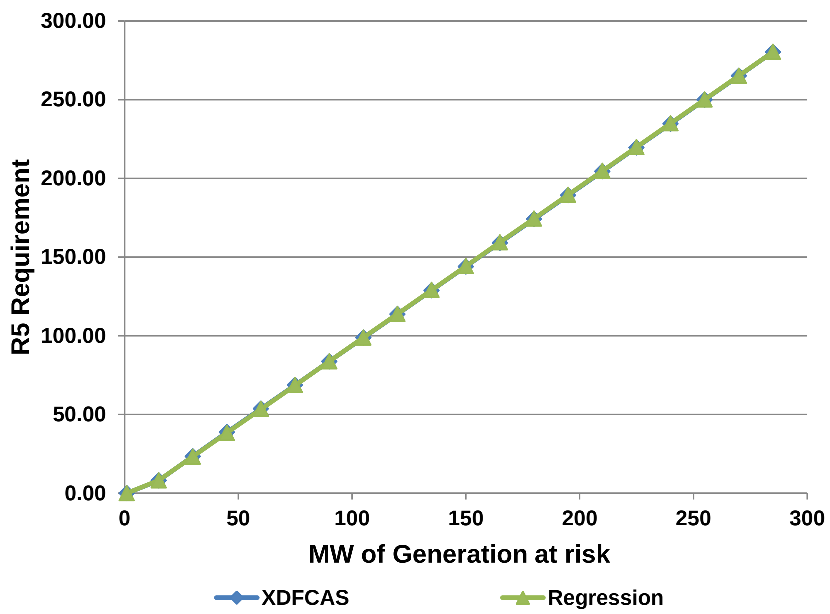


Table 3-3 – South Australia Raise 5 minute coefficients for a generator trip

Term	Segment 1
Intercept	0.143
SA Demand	-0.005
SA Inertia	0.00013
SA MW at Risk	1.0084

3.2. South Australia Island Load Trip

The following limit equations are to be used when South Australia is an island for loss of the largest load (Olympic Dam) or for the loss of Murraylink for SA to Vic to transfers.

Figure 3-4 – Lower 6 second requirement for South Australian demand of 1600 MW and inertia = 6500 MWs

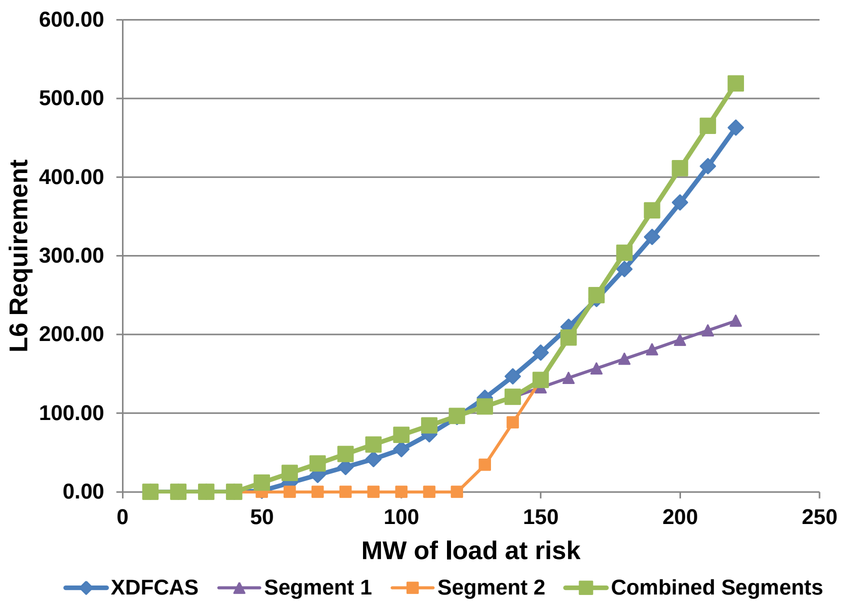


Table 3-4 – South Australia Lower 6 second coefficients for a load trip

Term	Segment 1	Segment 2
Intercept	23.7972	-96.0062
SA Demand	-0.0337	-0.1298
SA Inertia	-0.00284	-0.05566
SA MW at Risk	1.2089	5.3842

Figure 3-5 – Lower 60 second requirement for South Australian demand of 1600 MW and inertia = 6500 MWs

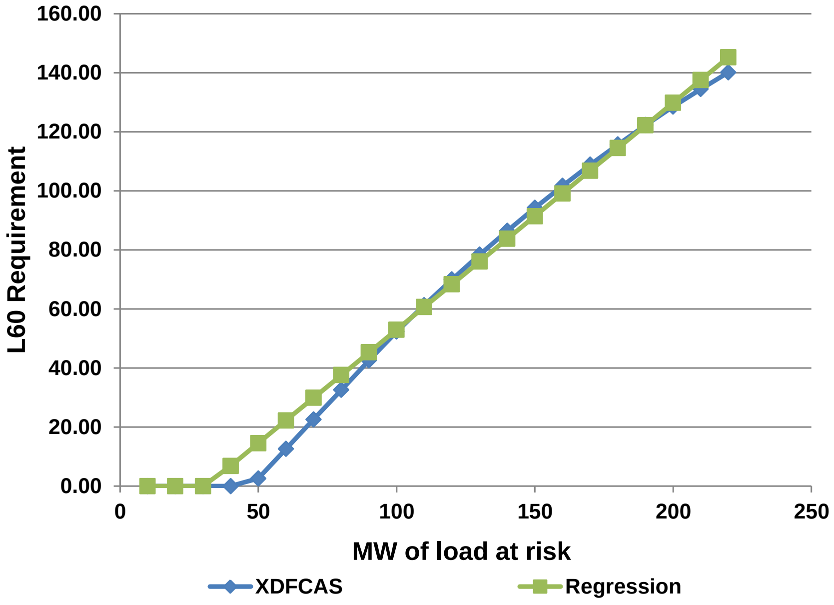


Table 3-5 – South Australia Lower 60 second coefficients for a load trip

Term	Segment 1
Intercept	3.9107
SA Demand	-0.0199
SA Inertia	0.000622
SA MW at Risk	0.7687

Figure 3-6 – Lower 5 minute requirement for South Australian demand of 1600 MW and inertia = 6500 MWs

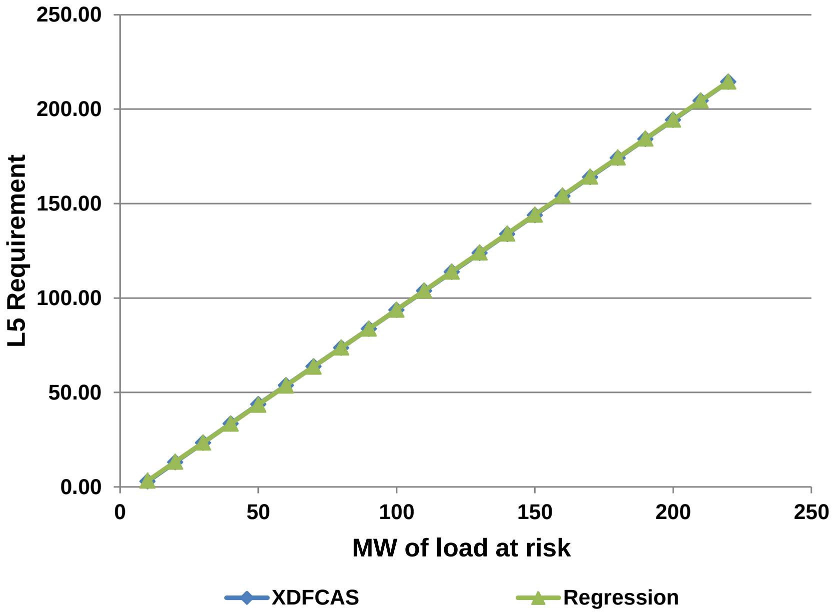


Table 3-6 – South Australia Lower 5 minute coefficients for a load trip

Term	Segment 1
Intercept	-0.0229
SA Demand	-0.0046
SA Inertia	0.000102
SA MW at Risk	1.0063

MEASURES AND ABBREVIATIONS

3.3. Units of measure

Unit of measure	Expanded name
MW	A watt (W) is a measure of power and is defined as one joule per second and it measures the rate of energy conversion or transfer. A Megawatt is one million watts.

3.4. Abbreviations

Note: the inertia values in this document are in MWs unlike the inertia values from AEMO's EMS which are expressed in 100 MVA base.

Abbreviation	Expanded name
Basslink (Tas to Vic)	MW Transfer from Tasmania to Victoria via Basslink (measured on the Tasmanian side)
Basslink headroom	80 % of the available headroom on Basslink capped at 100. The headroom is calculated as: ***80% x (If Basslink current flow > 50 MW then*** ***Basslink Bid availability – Basslink current flow*** ***Else if Basslink current flow < -50 MW then*** ***Abs (Basslink current flow) – 50*** ***Else 0)***
Bluff Point MW	MW output of the Bluff Point wind farm
Musselroe MW	MW output of the Musselroe wind farm
SA Demand	Summation of the scheduled, semi-scheduled and non-scheduled generators in South Australia
SA Inertia	Inertia of the South Australian generators in MWs
SA MW at Risk	Generator(s), Load(s) at risk in South Australia. Murraylink is also considered a generator (for Vic to SA flows) and a load (for SA to Vic flows).
Studland Bay MW	MW output of the Studland Bay wind farm
Tas MW at Risk	Generator(s) or Load(s) at risk in Tasmania
Tasmanian Demand	Summation of the scheduled, semi-scheduled and non-scheduled generators in Tasmania
Tasmanian Inertia	Inertia of the Tasmanian generators in MWs
Tasmanian Inertia - Contingency	The inertia of the Tasmanian generators (scheduled and non-scheduled) in MWs minus the inertia of the contingent generator(s)

GLOSSARY

Term	Definition
Constraint equation	These are the mathematical representations that AEMO uses to model power system limitations and FCAS requirements in NEMDE.
Constraint function	A group of RHS terms that can be referenced by one or more constraint equation RHSs. These are used where a common calculation is required multiple times (such as a complex stability limit or a calculation for a sub-regional demand). These have been referred to as generic equations, base equations or shared expressions in the past.
Constraint set	A grouping of constraint equations that apply under the same set of power system conditions, either for system normal or plant outage(s). AEMO uses constraint sets to efficiently activate / deactivate constraint equations.
Mainland	The NEM regions: Queensland, New South Wales, Victoria and South Australia
System Normal	The configuration of the power system where: • All transmission elements are in service, or • The network is operating in its normal network configuration