Electricity spot prices above $5000/MWh

South Australia, 1 December 2016 (10.30 am)

2 February 2017

AUSTRALIAN ENERGY REGULATOR

Inquiries about this publication should be addressed to:

Australian Energy Regulator
GPO Box 520
MELBOURNE VIC 3001

Tel: (03) 9290 1444
Fax: (03) 9290 1457

Email: AERInquiry@aer.gov.au
AER Reference: 61335-D16/163862

Amendment Record

Version	Date	Pages
1 version for publication	02/02/2017	26

Contents

1 Introduction....4

2 Summary....5

3 Analysis....6

3.1. Network availability and rebidding....6

3.1.1 Mortlake rebidding and imports....8

3.1.2 Pricing outcomes....9

Appendix A: Significant rebids....13

Appendix B: Relevant Market Notices....16

Appendix C: Price setter....20

Appendix D: Closing bids....22

Appendix E: Management of constraints....25

1 Introduction

The AER is required to publish a report whenever the electricity spot price exceeds $5000/MWh.[1] The report:

- describes the significant factors contributing to the spot price exceeding $5000/MWh, including withdrawal of generation capacity and network availability;
- assesses whether rebidding contributed to the spot price exceeding $5000/MWh;
- identifies the marginal scheduled generating units; and
- identifies all units with offers for the trading interval equal to or greater than $5000/MWh and compares these dispatch offers to relevant dispatch offers in previous trading intervals.

On 1 December 2016 at 10.30 am, the spot price for electricity reached $9175/MWh in South Australia exceeding the $5000/MWh threshold. This report presents our analysis of the events in accordance with this obligation.

[1] This requirement is set out in clause 3.13.7 (d) of the National Electricity Rules.

2 Summary

On 1 December 2016 at 10.30 am, the wholesale spot price for electricity in South Australia reached $9175/MWh.

The circumstances surrounding this high priced event were the result of the interaction between network constraints invoked by AEMO to manage an unplanned (forced) network outage in Victoria on one of the lines that comprise the Heywood interconnector and generation in the proximity of the outage. Interestingly, rebidding in Victoria from high prices to low prices contributed to the high priced event in South Australia.

As a result of the unplanned outage, AEMO invoked a network constraint to manage the resulting voltage imbalances in the network. This constraint reduces the Heywood interconnector's import limit into South Australia when either one of the two generators at Mortlake Power Station, which is located adjacent the interconnector in Victoria's south west, are operating.

While Mortlake was originally not forecast to operate, at around 10 am Origin Energy rebid the capacity of Mortlake unit two to the price floor. Mortlake unit two started generating, forcing the flow on the Heywood interconnector to reverse and flow from South Australia into Victoria - counter-price. This created power system security issues in South Australia and caused the 5 minute dispatch price to rise to the market price cap from 10 am to 10.20 am.

At around 10.20 am AEMO directed Origin Energy to shut down the Mortlake generator restoring the security of the power system.

Rebidding of capacity from low to high prices did not contribute to the high prices in this event. In response to the high price event, participants rebid capacity from high to low prices resulting in two dispatch intervals at the price floor.

3 Analysis

Table 1 shows the actual and forecast spot price, demand and generator availability for the 10 am, 10.30 am and 11 am trading intervals. The spot price in South Australia exceeded $5000/MWh for the 10.30 am trading interval (in bold) and two other trading intervals associated with the same event.

Table 1: Actual and forecast spot price, demand and availability

Trading interval	Price ($/MWh)		Demand (MW)		Availability (MW)	
	Actual	4 hr forecast	Actual	4 hr forecast	Actual	4 hr forecast
10 am	2551	80	1294	1173	1856	1883
10.30 am	**9175**	**64**	**1239**	**1175**	**1753**	**1890**
11 am	-113	84	1192	1131	1761	1899

Table 1 shows that the high prices were not forecast in advance. Demand during the 10.30 am trading interval, in which the high price occurred, was around 60 MW more than forecast. Availability was 137 MW less than forecast, due to lower than forecast wind and the physical withholding of capacity from Mintaro and Port Lincoln.[2]

3.1 Network availability

Maintenance was planned on the Heywood Interconnector putting South Australia on a single contingency with local FCAS regulation requirements invoked. This outage commenced at 6 am on 30 November and was completed at 9.46 pm on 1 December 2016. During this planned outage at 12.16 am on 1 December an unplanned outage, or fault, of the parallel Moorabool to Tarrone 500kV line occurred separating South Australia from the NEM.[3] At 12.30 am, following the separation, AEMO invoked the V_HYML1_4 constraint to manage voltage imbalances in the Victorian network close to the South Australian border.[4] The only controllable variables in this constraint are flows on the Heywood interconnector and the 540 MW Mortlake power station, located next to the Heywood interconnector in south west Victoria.[5] This constraint reduces the Heywood interconnector's import limit into South Australia if either of the two Mortlake units are generating. The constraint is not applicable when neither or both Mortlake units are generating.

Figure 1 shows a simplified representation of the network involved in the constraint after the unplanned outage occurred, the significant generators and their factors (green

2 Physical withholding refers to bidding behaviours by participants in which the capacity of plant is not bid to high prices but the available capacity of the plant is set to zero.

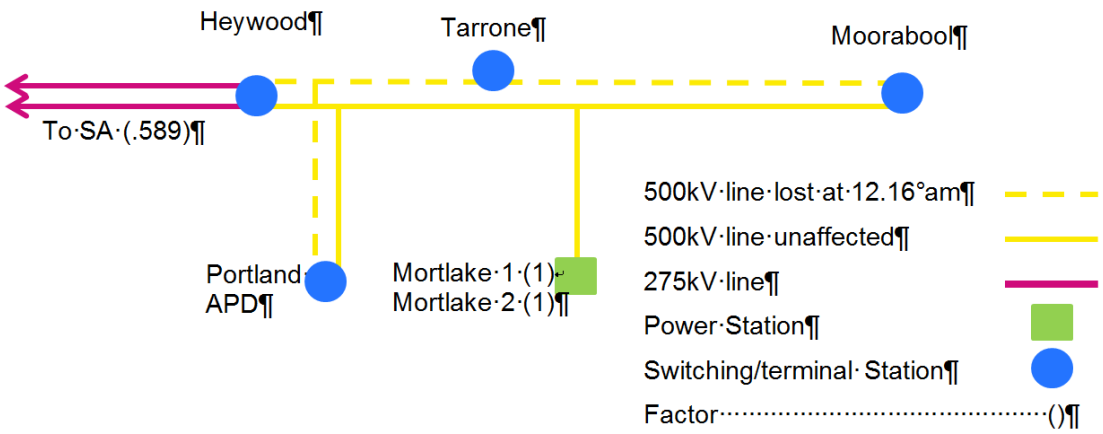
3 For details of the event that occurred at 12.16 am, refer to the 1 Dec $5000/MWh (12.16 am event) report.

4 Since the high price event on 1 December, AEMO has removed the constraint that increases flow across the Heywood interconnector from South Australia to Victoria as a result of one Mortlake Power Station unit increasing generation. AEMO have advised that due to close to real time monitoring in place at APD, combined with the current reduction in the APD's load following this event, the need to manage the voltage when an outage occurs on lines near APD is not currently required.

5 For details on management of constraints, see Appendix E.

square), significant substations (blue dots) and the high voltage lines (yellow and pink lines). Mortlake power station (green square) is comprised of two units, each assigned a factor of one, meaning each unit has a significant impact on the value of the constraint. As discussed, the constraint is only effective if either one of these generators is operating.

Figure 1: Network diagram



Day-ahead, Origin Energy offered all of the 270 MW capacity of Mortlake unit two at the price cap and unit one was bid unavailable. Victorian prices were forecast to be around $60/MWh, the available Mortlake unit was not forecast to be dispatched and consequently the constraint was not forecast to have any affect.

The change in network capability driven by the dispatch of Mortlake, after it was rebid to low prices, materially contributed to price outcomes. Table 2 shows the significant difference between actual and forecast import limits on the Heywood interconnector four and 12 hours ahead.

Table 2: Heywood Interconnector - Actual and forecast network capability

Trading interval	Flows into South Australia (MW)			Import limit (MW)		
	Actual	4 hr forecast	12 hr forecast	Actual	4 hr forecast	12 hr forecast
10 am	169	389	250	127	500	250
10.30 am	-431	395	250	-530	501	250
11 am	-56	291	250	-46	495	250

The large change in actual flow across the Heywood interconnector from 10 am to 10.30 am was due to the V_HYML1_4 constraint in Victoria violating when Mortlake Power Station started and its output increased. The rebidding by Origin Energy for Mortlake is discussed in the next section. Table 3 shows that at the time of the high prices Murraylink was limited to importing between 190 MW and 220 MW (its nominal

limit) into South Australia, close to forecast and unaffected by the dispatch of Mortlake.[6]

Table 3: MurrayLink - Actual and forecast network capability

Trading interval	Flows into South Australia (MW)			Import limit (MW)		
	Actual	4 hr forecast	12 hr forecast	Actual	4 hr forecast	12 hr forecast
10 am	219	36	179	220	209	220
10.30 am	193	40	133	193	213	220
11 am	52	27	127	125	205	220

3.1.1 Mortlake rebidding and imports

There was no significant rebidding of capacity from low to high prices in South Australia that contributed to the high priced outcomes. However, rebidding capacity for Origin Energy's Mortlake Power Station in Victoria from high to low prices was the dominant trigger for high prices in South Australia. The rebidding of ramp down rates for Mortlake by Origin Energy to the minimum allowed under the Rules prolonged these prices.

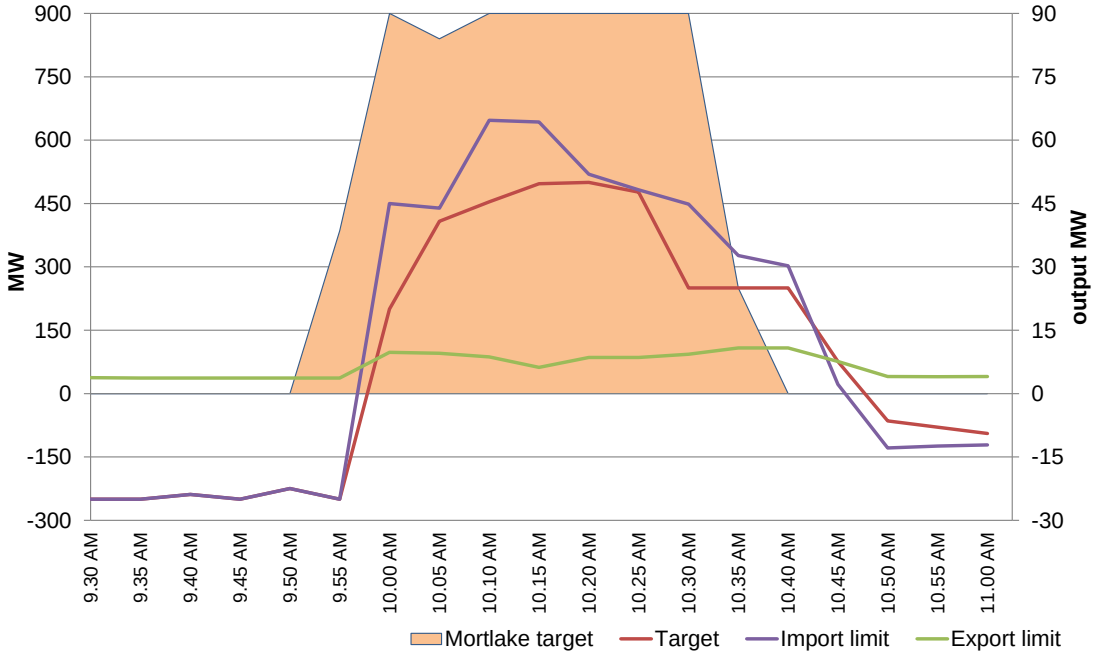
At 9.41 am, effective from the 9.50 am dispatch interval, Origin Energy rebid the entire 270 MW capacity of Mortlake unit two from the price cap of $14 000/MWh to the price floor of -$1000/MWh. As a result of this rebid, Mortlake unit two received a start signal at 9.50 am and a target of 39 MW at 9.55 am. At 10 am, once the output of Mortlake unit two was evident to NEMDE, the network constraint violated.[7]

Figure 2 highlights the relationship between flow on the Heywood interconnector and output from Mortlake. At 9.55 am, imports into South Australia were at their limit of 250 MW. At 10 am, as output from Mortlake Power Station increased (light orange area), and the constraint violated, flows (red line) across the interconnector from Victoria to South Australia decreased (negative values) and began to flow from South Australia into Victoria (positive values) at 200 MW. The import limit (purple line) moved above the export limit (green line), effectively forcing flow out of South Australia. This situation continued until 10.45 am and peaked at 10.20 am when South Australia was exporting 500 MW into Victoria. The power system was insecure as the Heywood interconnector was operating materially above its constrained export limits, as seen in Figure 2.

6 Limits were reduced by a constraint managing the outage of the New South Wales MurrayLink runback scheme.

7 Origin took similar action on the previous day, where they rebid 150 MW of capacity of one unit at Mortlake to the price floor. A similar constraint bound and the price in South Australia reached the price cap for two dispatch intervals. For details on this event, see the Electricity weekly report 27 November – 3 December 2016.

Figure 2: Heywood interconnector flows and Mortlake output



Generation in South Australia ramped up at their offered rate within the dispatch interval but it was not sufficient to satisfy the constraint and it violated at 10 am. South Australia was exporting into Victoria counter-price and the dispatch price in South Australia reached the market price cap.

At 9.59 am, effective from the 10.10 am dispatch interval, Mortlake rebid its ramp down rate from 13 MW/min to 3 MW/min, reducing the rate at which Mortlake's generation could be reduced, even though the constraint was violating.

At around 10.20 am AEMO directed Origin Energy to reduce generation at Mortlake to zero and de-synchronise, until further notice, to return the power system to a secure state. This was notified to the market in market notice 56046. As a result, at 10.25 am, effective from the 10.35 am dispatch interval, Origin Energy rebid Mortlake unit two's availability to zero and its ramp down rate from 3 MW/min to 13 MW/min. The reason given was '1023P CHANGE IN AVAIL - AEMO DIRECTION SL'.

The increase in the units ramp down rate, led to its output dropping to zero in two dispatch intervals and by the 10.40 am dispatch interval, Mortlake unit two was targeted off. At 10.45 am the constraint was no longer violating.

The direction was withdrawn at 3.45 pm but Mortlake did not generate after that time.

Details of Mortlake rebids can be found in Appendix A.

Appendix B outlines the relevant market notices published by AEMO.

3.1.2 Pricing outcomes

The dispatch price in South Australia was at or near the price cap from 10 am to 10.20 am inclusive and dropped to the price floor on two occasions at 10.30 am and 10.45 am. This led to the high trading interval prices at 10 am and 10.30 am and a negative price at 11 am.

Table 4 shows the dispatch and spot prices in South Australia as well as a general price setting classification. Only one of the prices close to the market price cap was set by generation in South Australia, the other prices were set by generation in other regions of the NEM or by the co-optimisation process between energy and Frequency Control Ancillary Services (FCAS).

Table 4: Dispatch and spot prices and price setting classification

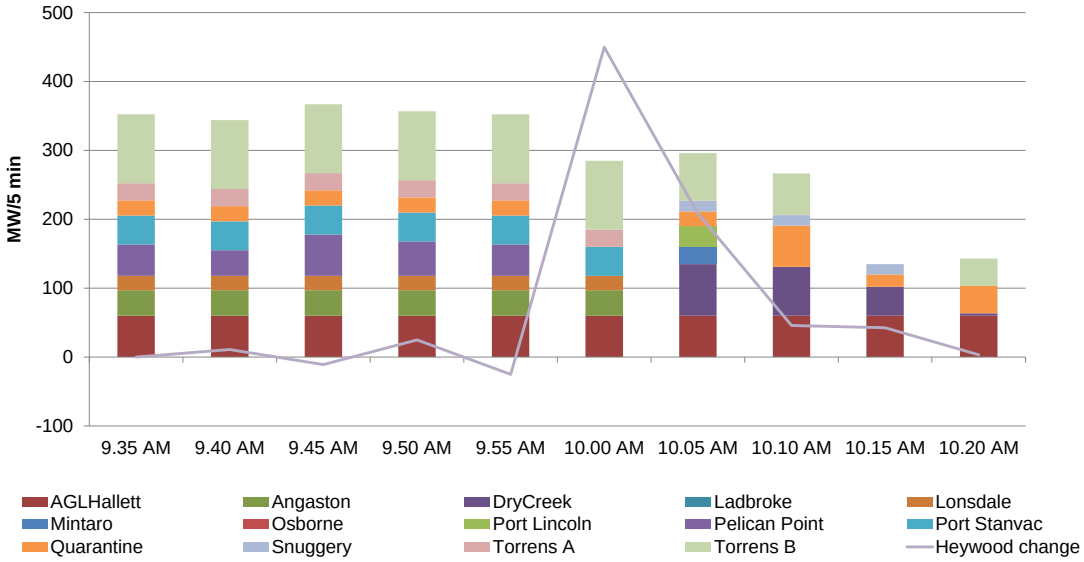
Dispatch Interval	Spot Price $/MWh	Dispatch Price $/MWh	Price setting classification
9.35 am		300	Local generation
9.40 am		300	Local generation
9.45 am		110	Interstate generation
9.50 am		300	Local generation
9.55 am		300	Local generation
10 am	2551	14 000	Local generation ramp up limits
10.05 am		**14 000**	**Co-optimisation of Energy and FCAS**
10.10 am		**14 000**	**Co-optimisation of Energy and FCAS**
10.15 am		**14 000**	**Co-optimisation of Energy and FCAS**
10.20 am		**13 999**	**Local generation**
10.25 am		**54**	**Interstate generation**
10.30 am	**9175**	**-1000**	**Local generation that was rebid to the price floor**
10.35 am		85	Co-optimisation of Energy and FCAS
10.40 am		70	Interstate generation
10.45 am		-1000	Local constrained generation
10.50 am		56	Interstate generation
10.55 am		57	Interstate generation
11 am	-113	57	Interstate generation

Price setting classification: 10 am – Local generation ramp up limits

At 10 am there was not sufficient ramp up rate available from generation in South Australia to meet the 450 MW change in flow on the Heywood interconnector to satisfy the constraint. The constraint violated and the dispatch price went to the price cap.

Figure 3 shows the cumulative effective ramp up rate of South Australian generation (stacked bars) and the rate of change on the Heywood interconnector for each dispatch interval (grey line). Most notably, flows on the Heywood interconnector changed by 450 MW between the 9.55 am and 10 am dispatch intervals. While the rate of change on the interconnector was 450 MW in 5 minutes, the local generation in South Australia could only provide an extra 285 MW due to ramp up constraints.

Figure 3: Effective ramp up rates from South Australian generators and the MW change on Heywood



10.05 am and 10.15 am inclusive and 10.35 am, Co-optimisation of Energy and FCAS

Between 10.05 am and 10.15 am inclusive and at 10.35 am the price was being set by the co-optimisation of the energy and FCAS markets.

The National Electricity Market Dispatch Engine (NEMDE) co-optimises FCAS and energy offers to ensure the most cost effective pricing solution. Similar to energy offers, participants may offer capacity into each FCAS market in different price bands. NEMDE co-optimises the dispatch targets accounting for current energy dispatch levels, FCAS requirements and generator offers for energy and FCAS. While a generator may offer a large volume of capacity into the energy market, the effective available capacity may be less depending on how much FCAS the generator is providing at the time.

At 10 am South Australia was exporting into Victoria causing a requirement for lower contingency services as South Australia was on a single contingency. The requirement was met by high priced lower contingency services, the offers for these services were co-optimised with energy, leading to high energy prices (as shown in Appendix C). High FCAS prices were calculated by NEMDE but were capped at $300/MW because events on 25 November 2016 had triggered FCAS administration pricing. AEMO notified the market of this situation in market notice 55999.

Price setting classification: Local generation that was rebid to the price floor

At 10.30 am the dispatch price fell to the price floor as a result of participants in South Australia rebidding around 1000 MW of capacity to the price floor. Following a high dispatch price it is not unusual for generators to seek to increase revenue by rebidding capacity to low prices bands to facilitate higher dispatch levels during the high priced trading interval.

Significant rebids of capacity from participants with generation in South Australia included:

- 474 MW by AGL at Torrens Island from greater than $55/MWh to -$1000/MWh
- Another 500 MW was rebid to the price floor by peaking plant

A summary of the rebids in response to the high prices are in Appendix A.

Figure 4 shows closing bids for participants with generation in South Australia, total regional generation dispatched (orange) and the 5 minute dispatch price (grey).

Figure 4: Closing bids of South Australia generators, output and dispatch price

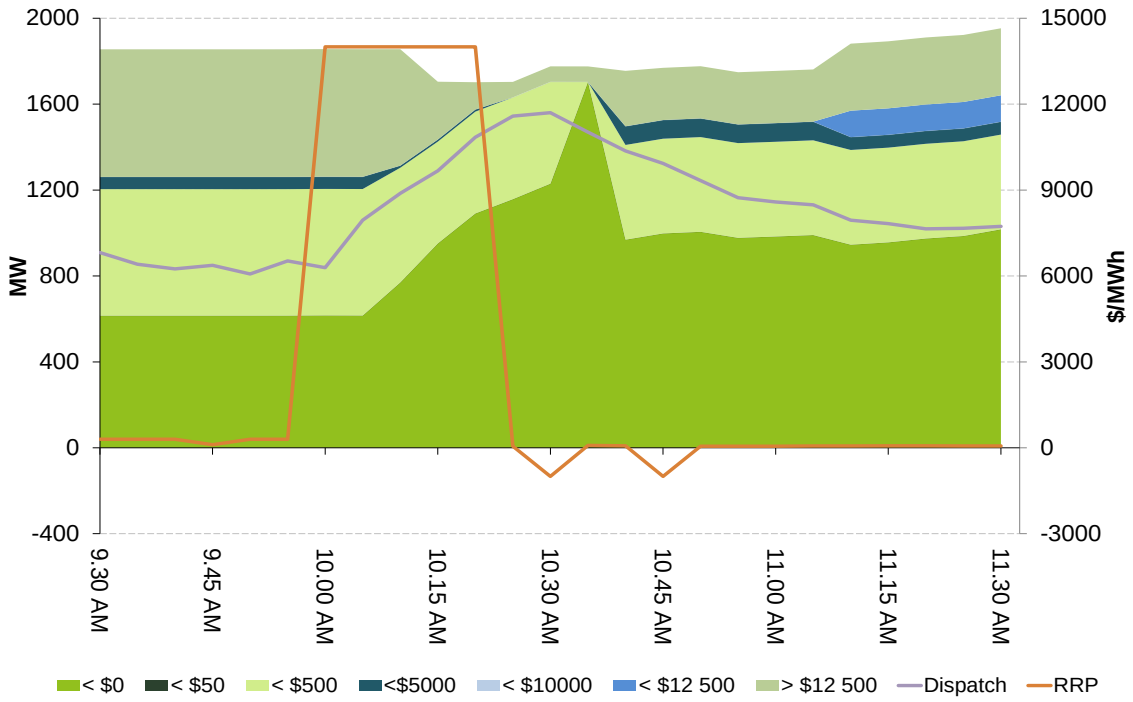


Figure 4 shows the rapid increase in negatively priced capacity (bottom green section) from 10.10 am. This resulted in the dispatch price falling to the price floor for the 10.30 am dispatch interval.

Price setting classification: Local Constrained generation

At 10.45 am the dispatch price reached the price floor because high priced capacity at AGL's Torrens Island units were ramp down limited and EnergyAustralia's Hallett unit was unable to set price because they had been declared non-conforming by AEMO in market notice 56043. Consequently, these stations could not set the price and the next available unconstrained generator offers were at the price floor.

Appendix C details the generators involved in setting the price during the high-price periods, and how that price was determined by the market systems.

The closing bids for all participants with generation in South Australia and capacity priced at or above $5000/MWh for the high-price periods are set out in Appendix D.

Australian Energy Regulator

February 2017

Appendix A: Significant rebids

Table 5 shows significant rebids by Mortlake Power Station in Victoria and South Australian participants for the 10.30 am trading interval. It details the time the rebid was submitted and used by the dispatch process, the capacity involved, the change in the price of the capacity was being offered and the rebid reason.

Table 5: Significant energy rebids for 10.30 am

Submit time	Time effective	Participant	Station	Capacity rebid (MW)	Price from ($/MWh)	Price to ($/MWh)	Rebid reason
9.41 am	9.50 am	Origin Energy	Mortlake (Unit 2 only)	270	14 000	-1000	0937A CHGE IN FCAST - INC VIC DEM 5PD 5154>30PD 5079 @ 945 SL
9.50 am	10.05 am	Energy Australia	Hallett	23	13 999	-1000	0945~A~BAND ADJ DUE TO MATERIAL CHANGE IN IC LIMITS - CONSTRAINT EXTENDED SL ~
9.58 am	10.05 am	Energy Australia	Hallett	17	13 999	-1000	0955~A~BAND ADJ DUE TO UNFORECAST MPC SL~
9.59 am	10.10 am	Origin Energy	Quarantine	22	14 000	-1000	0955A UNFORECAST DISPATCH VOLATILITY SL
9.57 am	10.05 am	Engie	Dry Creek	46	≥1498	-1000	0956A RESPOND TO UNFORECAST $14000 SAPRICE
9.59 am	10.05 am	Engie	Dry Creek	46	13 300	-1000	0958A RESPOND TO UNFORECAST SA MPC PRICE
9.59 am	10.05 am	Engie	Snug	42	1499	-1000	0958A RESPOND TO UNFORECAST SA MPC PRICE
10 am	10.10 am	Engie	Pelican Point	60	300	-1000	0959A RESPOND TO UNFORECAST SA MPC

Submit time	Time effective	Participant	Station	Capacity rebid (MW)	Price from ($/MWh)	Price to ($/MWh)	Rebid reason
10.02 am	10.10 am	Snowy Hydro	Angaston, Lonsdale Port Stanvac,	100	≥13 958	≤-997	10:00:06 A SA 5MIN ACTUAL PRICE $13,926.26 HIGHER THAN 30MIN PD 10:05@09:31 ($14,000.00)
10.03 am	10.10 am	Engie	Mintaro	-84	14 000	N/A	1003A AVOID UNECONOMICAL DISPATCH
10.03 am	10.10 am	Engie	Port Lincoln	-67	14 000	N/A	1003A AVOID UNECONOMICAL DISPATCH
10.05 am	10.15 am	Engie	Dry Creek	46	13 300	-1000	1004A RESPOND TO UNFORECAST MPC SA
10.06 am	10.20 am	Origin	Quarantine	96	14 000	-1000	1000A CONSTRAINT MANAGEMENT - V_HYML1_4 SL
10.10 am	10.20 am	Energy Australia	Hallett	65	≥579	-1000	1000~A~BAND ADJ DUE TO UNFORECAST MPC SPIKE ~
10.16 am	10.35 am	Engie	Port Lincoln	67	N/A	-1000	1016A RESPOND TO 5MIN PD HHE 11:00 SA $13,999.99
10.22 am	10.30 am	AGL	Torrens	474	>60	-1000	1020~A~040 CHG IN AEMO DISP~46 PRICE DECREASE VS 5MIN PD SA $431.18 SL

Table 6 shows the ramp down rate rebidding. It details the time the rebid was submitted and used by the dispatch process, the capacity involved, the change in the ramp down rate and the rebid reason.

Table 6: Significant ramp down rate rebids for 10.30 am

Submit time	Time effective	Participant	Station	Capacity rebid (MW/min)	Ramp down rate from (MW/min)	Ramp down rate to (MW/min)	Rebid reason
9.59 am	10.10 am	Origin Energy	Mortlake	270	13	3	0955A CONSTRAINT MANAGEMENT - V_HYML1_4 SL
9.59 am	10.10 am	Origin Energy	Ladbroke	86	16	6	0955A UNFORECAST DISPATCH VOLATILITY SL
9.59 am	10.10 am	Origin Energy	Quarantine Unit 5	120	10	3	0955A UNFORECAST DISPATCH VOLATILITY SL
10.10 am	10.20 am	Origin Energy	Quarantine Units 1 - 4	96	12	4	1008A CONSTRAINT MANAGEMENT - V_HYML1_4 SL
10.25 am	10.35 am	Origin Energy	Mortlake	270	3	13	1023P CHANGE IN AVAIL - AEMO DIRECTION SL

Appendix B: Relevant Market Notices

Market Notice	Type	Date of issue	Last Changed
55999	ADMINISTERED PRICE CAP	01/12/2016 03:56:58	01/12/2016 03:56:58

External Reference

[EventId:106] AP STARTED for market ancillary services in SA at 01 December 2016 04:00

Reason

AEMO ELECTRICITY MARKET NOTICE

Issued by Australian Energy Market Operator Ltd at 0355 hrs on 1 December 2016

ADMINISTERED PRICE PERIOD DECLARED in SA region.

AEMO has determined that the rolling sum of the uncapped market ancillary Lower Reg, Raise Reg services(s) prices for the SA region over the previous 2016 dispatch intervals has exceeded 6 times the cumulative price threshold (CPT) of $210,100.00.

In accordance with Clause 3.14 of the National Electricity Rules, AEMO has determined that an administered price period will commence at the dispatch interval starting 0400 hrs on 1 Dec 2016 and will continue through to the end of that trading day.

An administered price cap (APC) of 300 $/MWh will apply to all dispatch intervals during this administered price period. This APC will apply to all market ancillary service prices in the SA region.

An administered floor price (AFP) of 0 $/MWh AFP will apply to all market ancillary service prices.

AEMO will continue to monitor the rolling sum of the uncapped market ancillary service prices and issue further market notices as required.

This is an AEMO autogenerated Market Notice.

Market Notice	Type	Date of issue	Last Changed
56043	NON-CONFORMANCE	01/12/2016 10:45:12	01/12/2016 10:45:12

External Reference

NON-CONFORMANCE Region SA1 Thursday, 1 December 2016

Reason

AEMO ELECTRICITY MARKET NOTICE

NON-CONFORMANCE SA1 Region Thursday, 1 December 2016

AEMO declared a schedule generating unit non-conforming

Unit: AGLHAL

Duration: 01/12/2016 10:25 to 01/12/2016 10:45

Amount: -57 MW

Constraint: NC-S_AGLHAL

Auto-generated on behalf of Manager NEM Real Time Operations

Market Notice	Type	Date of issue	Last Changed
56046	MARKET INTERVENTION	1/12/2016 10:59:08 AM	1/12/2016 10:59:08 AM

External Reference

Direction - Victoria Region region 1/12/16

Reason

AEMO ELECTRICITY MARKET NOTICE.

Direction - Victoria Region region 1/12/16

In accordance with clause 4.8.9 of the National Electricity Rules AEMO has issued a direction to a participant in the Victoria region.

The direction was necessary to re-establish the power system to a secure operating state,

The direction was issued at 1030 hrs and is expected to stay in place until further notice

Manager NEM Real Time Operations

Market Notice	Type	Date of issue	Last Changed
56053	MARKET INTERVENTION	01/12/2016 11:09:42	01/12/2016 11:09:42

External Reference

Direction - Origin Energy - 1/12/16

Reason

AEMO ELECTRICITY PARTICIPANT NOTICE.
Direction - Origin Energy - 1/12/16

In accordance with clause 4.8.9 of the National Electricity Rules AEMO is issuing a direction to Origin Energy to take the following action.

Reduce generation at Mortlake Power Station unit 12 to zero and de-synchronise

The direction is issued subject to the Registered Participant's best endeavours to comply with it unless compliance would be a hazard to public safety or materially risk damaging equipment or contravene any other law.

The direction is issued at 1030 hrs and is expected to stay in place until further notice

Manager NEM Real Time Operations

Market Notice	Type	Date of issue	Last Changed
56067	MARKET INTERVENTION	1/12/2016 3:45:17 PM	1/12/2016 3:45:17 PM

External Reference

Direction ceased - Victoria Region region 1/12/16

Reason

AEMO ELECTRICITY MARKET NOTICE.

Direction - Victoria Region region 1/12/16

In accordance with clause 4.8.9 of the National Electricity Rules AEMO has issued a direction to a participant in the Victoria region.

The direction was necessary to re-establish the power system to a secure operating state,

The direction was issued at 1030 hrs and ceased at 1545hrs /1/2/16

Manager NEM Real Time Operations

Market Notice	Type	Date of issue	Last Changed
56068	MARKET INTERVENTION	01/12/2016 15:47:05	01/12/2016 15:47:05

External Reference

Direction ceased - Origin Energy - 1/12/16

Reason

AEMO ELECTRICITY PARTICIPANT NOTICE.

Direction - Origin Energy - 1/12/16

Refer participant notice 56021

In accordance with clause 4.8.9 of the National Electricity Rules AEMO is issuing a direction to Origin Energy to take the following action.

Reduce generation at Mortlake Power Station unit 12 to zero and de-synchronise

The direction is issued subject to the Registered Participant's best endeavours to comply with it unless compliance would be a hazard to public safety or materially risk damaging equipment or contravene any other law.

The direction is issued at 1030 hrs and ceases at 1545 hrs 1/12/16

Manager NEM Real Time Operations

Appendix C: Price setter

The following table identifies for the trading interval in which the spot price exceeded $5000/MWh, each five minute dispatch interval price and the generating units involved in setting the energy price. This information is published by AEMO.[8] The 30-minute spot price is the average of the six dispatch interval prices. The dispatch prices that are in italics are capped at the price cap of $14 000/MW when published by AEMO.

Table 7: price setter for the 10.30 am trading interval

DI	Dispatch Price	Participant	Unit	Service	Offer price	Marginal change	Contribution
10:05	*$16 855.08*	AGL	TORRA1	Energy	$484.99	1	$484.99
		Engie	PPCCGT	Lower 5 min	$14 000	1	$14 000
		AGL	TORRA1	Lower 5 min	$13 799.9	-1	-$13 800
		AGL	TORRA1	Lower 60 sec	$0.03	-0.83333	-$0.025
		AGL	TORRB3	Lower 60 sec	$13 799.9	0.83333	$11 499.95
		Engie	PPCCGT	Lower 6 sec	$14 000	0.33333	$4666.62
		AGL	TORRA1	Lower 6 sec	$0.03	-0.33333	-$0.01
		Hydro Tasmania	GORDON	Raise 60 sec	$2.39	0.83333	$1.99
		AGL	TORRA1	Raise 60 sec	$0.04	-0.83333	-$0.03
		Delta Electricity	VP5	Raise 6 sec	$5	0.33333	$1.67
		AGL	TORRA1	Raise 6 sec	$0.5	-0.33333	-$0.17
10:10	*$42 477.70*	AGL	TORRB3	Energy	$484.99	1	$484.99
		Origin	QPS5	Lower 5 min	$14 000	1	$14 000
		AGL	TORRB3	Lower 5 min	$11.99	-1	-$11.99
		AGL	TORRB2	Lower 60 sec	$13 799.9	5.55556	$76 666.67
		AGL	TORRB3	Lower 60 sec	$13 799.9	-5.55556	-$76 666.7
		Engie	PPCCGT	Lower 6 sec	$14 000	2	$28 000
		AGL	TORRB3	Lower 6 sec	$0.5	-2	-$1
		AGL	TORRB3	Raise 5 min	$0.9	-1	-$0.9
		AGL	TORRB4	Raise 5 min	$1.8	1	$1.8
		Hydro Tasmania	GORDON	Raise 6 sec	$5	2	$10
		AGL	TORRB3	Raise 6 sec	$2.6	-2	-$5.2
10:15	*$57 160.54*	AGL	TORRB4	Energy	$484.99	1	$484.99
		AGL	TORRB2	Lower 5 min	$9000	1	$9000
		AGL	LYA4	Lower 5 min	$9	1	$9
		AGL	TORRB4	Lower 5 min	$11.99	-1	-$11.99
		AGL	TORRB2	Lower 60 sec	$13 799.9	3.45455	$47 672.76
		AGL	TORRB4	Lower 60 sec	$1	-3.45455	-$3.45

[8] Details on how the price is determined can be found at www.aemo.com.au

DI	Dispatch Price	Participant	Unit	Service	Offer price	Marginal change	Contribution
		Delta Electricity	VP6	Raise 5 min	$2	1	$2
		AGL	TORRB4	Raise 5 min	$0.9	-1	-$0.9
		Hydro Tasmania	JBUTTERS	Raise 60 sec	$2.39	3.45455	$8.26
		AGL	TORRB4	Raise 60 sec	$1.48	-3.45455	-$5.11
		CS Energy	GSTONE4	Raise 6 sec	$4.96	2.14286	$10.63
		AGL	TORRB4	Raise 6 sec	$2.6	-2.14286	-$5.57
10:20	$13 998.99	Energy Australia	AGLHAL	Energy	$13 998.9	1	$13 998.99
10:25	$53.81	Origin	DDPS1	Energy	$49.98	0.98581	$49.27
		Engie	LOYYB1	Energy	$10.5	0.21621	$2.27
		Engie	LOYYB2	Energy	$10.5	0.21621	$2.27
10:30	-$1000	Origin	LADBROK1	Energy	-$1000	0.09091	-$90.91
		Origin	LADBROK2	Energy	-$1000	0.09091	-$90.91
		Origin	QPS1	Energy	-$1000	0.04545	-$45.45
		Origin	QPS2	Energy	-$1000	0.04545	-$45.45
		Engie	DRYCGT1	Energy	-$1000	0.08364	-$83.64
		Engie	DRYCGT2	Energy	-$1000	0.08364	-$83.64
		Engie	DRYCGT3	Energy	-$1000	0.08364	-$83.64
		Engie	SNUG1	Energy	-$1000	0.07636	-$76.36
		Snowy Hydro	ANGAST1	Energy	-$1000	0.06727	-$67.27
		Snowy Hydro	LONSDALE	Energy	-$1000	0.03818	-$38.18
		Snowy Hydro	PTSTAN1	Energy	-$1000	0.07636	-$76.36
		AGL	TORRA1	Energy	-$1000	0.21818	-$218.18
Spot Price		**$9175.47/MWh**					

Appendix D: Closing bids

Figures D1 to D5 highlight the half hour closing bids for participants in South Australia with significant capacity priced at or above $5000/MWh during the periods in which the spot price exceeded $5000/MWh. They also show generation output and the spot price. While Origin Energy offered around 500 MW of capacity, only 1 MW was priced above $5000/MWh when the price exceeded $5000/MWh.

Figure D1 – Origin (Ladbroke, Osborne, Quarantine) closing bid prices, dispatch and spot price

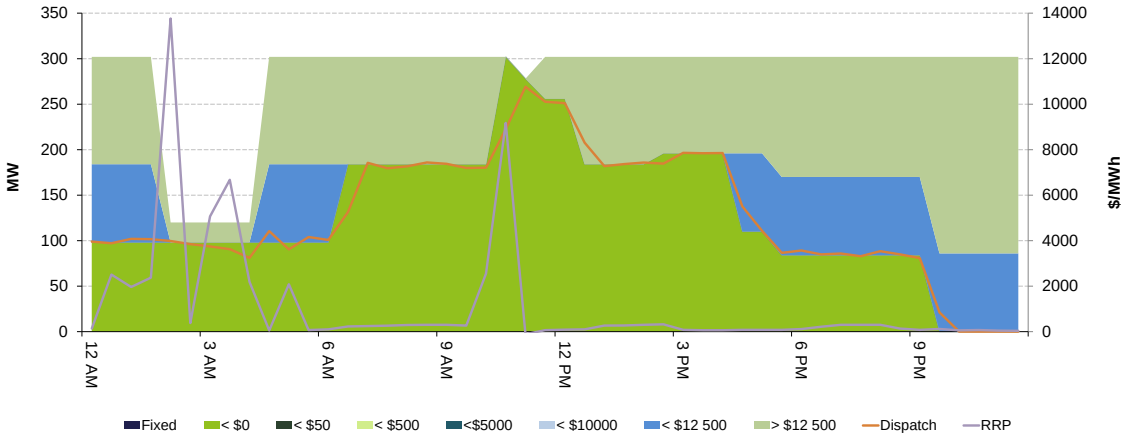


Figure D2 - AGL (Torrens Island, The Bluff, Hallett Wind Farm, North Brown Hill) closing bid prices, dispatch and spot price

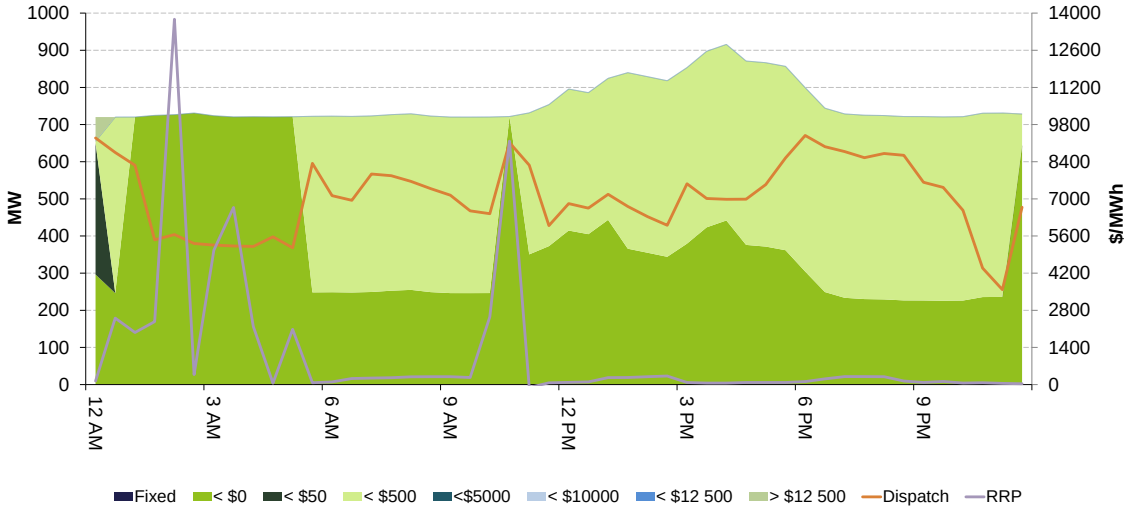


Figure D3 – Energy Australia (Hallett, Waterloo) closing bid prices, dispatch and spot price

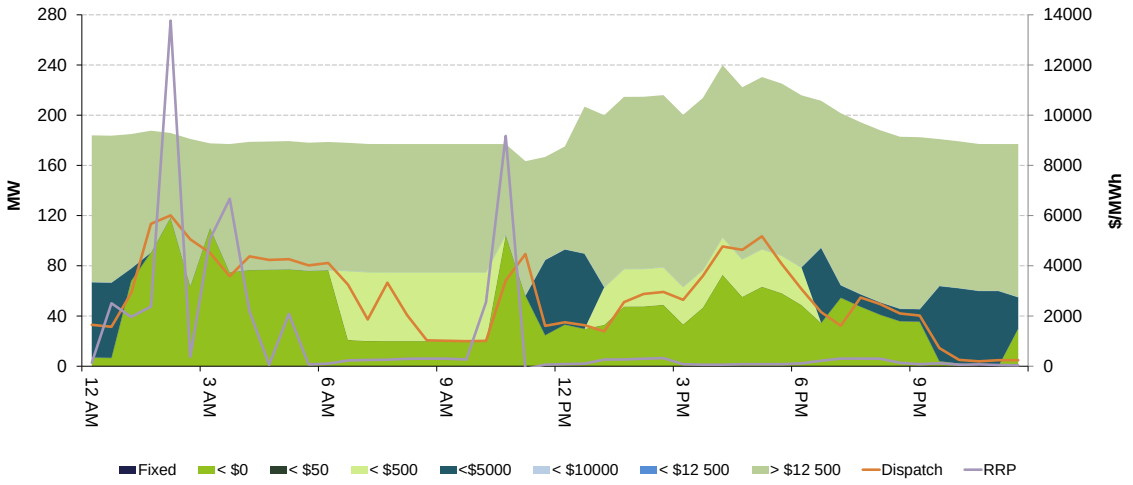


Figure D4 - Engie (Dry Creek, Mintaro, Port Lincoln, Snuggery) closing bid prices, dispatch and spot price

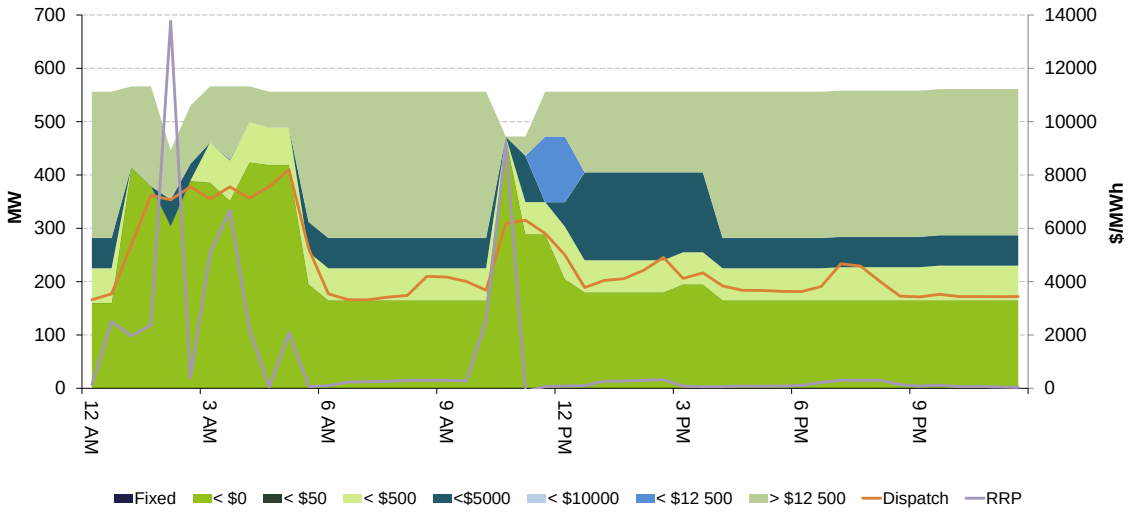
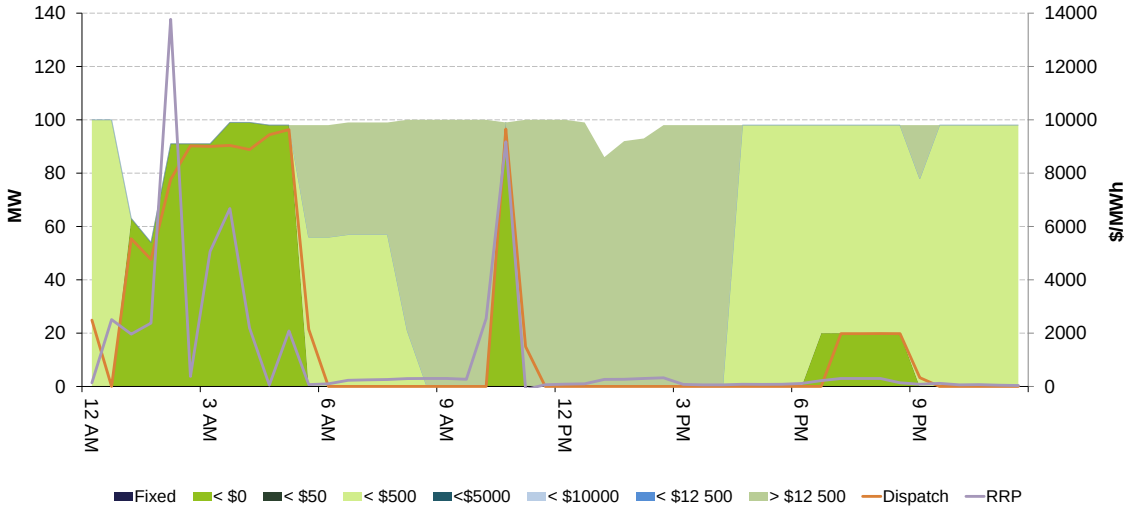


Figure D5 – Snowy Hydro (Lonsdale, Pt Stanvac and Angaston) closing bid prices, dispatch and spot price



Appendix E: Management of constraints

Constraint equations

One of AEMO's responsibilities as the market and system operator is to manage the network to ensure that transmission elements are not overloaded and system security is maintained. Where transmission elements become congested, they are referred to as being constrained. To manage network flows AEMO utilises constraint equations in the NEM dispatch engine (NEMDE), which runs every five minutes. A constraint equation is used to determine the optimal dispatch of generators (and scheduled loads) based on their offers (or bids) to manage flows on specific transmission lines (and other equipment) for each five minute dispatch interval.

Each constraint equation consists of a Left Hand Side (LHS) and a Right Hand Side (RHS). The RHS signifies the outer point of an outcome, beyond which a network element could become overloaded in the event of the 'credible contingency' the constraint is designed to manage.[9] A 'credible contingency' includes, for example, the loss of another line or a generator. The RHS contains all of the inputs that cannot be varied by NEMDE. These inputs include demand and the rating of the relevant transmission line (i.e. how much energy the line can carry without damaging the line or causing unsafe conditions). The LHS contains all of the inputs that can be varied by NEMDE to deliver an outcome that satisfies the requirement of the RHS. These inputs include output from generators and flow on interconnectors.

How NEMDE deals with constraints

Constraint equations are used in NEMDE together with generator offers to determine the optimal economic dispatch of generators to meet customer demand. All else being equal, if the flow over a particular element of the transmission system is within the requirements of the RHS, then the relevant constraint equation does not affect NEMDE dispatching generators in accordance with 'merit order' or 'economic dispatch' (by 'merit order' or 'economic dispatch' the AER means least-price offers of generation capacity are dispatched first). When the LHS of a particular constraint equation is equal to the RHS, the constraint is considered to be at its limit and is 'binding'. In this situation, NEMDE may need to affect dispatch outcomes to satisfy the constraint in preference to economic dispatch.

NEMDE is designed to avoid or minimise violating a constraint equation. Violations occur on the rare occasion when the LHS is greater than the RHS; that is, the flow over the line could be greater than its rating if the relevant credible contingency occurs in

9 If the constraint equation is not satisfied it is termed as 'violated'.

the next five minutes.[10] A binding constraint equation affects dispatch until the constraint no longer binds.[11]

To control the flow over a bound line to avoid violating the constraint, NEMDE attempts to change the LHS inputs. For example, NEMDE may try to increase (out of merit order) the output of generators or interconnectors closer to a relevant load/demand centre ('constrain on' a generator or interconnector). By increasing generation closer to the load/demand, it can in effect reduce the congestion on the transmission system. Alternatively, NEMDE can reduce (out of merit order) the output of generators or interconnectors that are a source of the flow over the transmission line ('constrain off' a generator or interconnector). NEMDE may also adopt a combination of these actions, depending on the specific constraint equation that is binding.

While the priority is system security and avoiding violations of constraints, NEMDE still attempts to find the least cost way of dispatching generation out of the options available. Therefore if, for example, there are several generators that could be 'constrained on', it will choose the lowest cost combination taking into account the prices offered and the coefficients (see discussion of coefficients below). The ability of the system to change generator outputs and interconnector flows to manage network congestion is termed 'fully co-optimised dispatch'.

When NEMDE changes flows over an interconnector (by 'constraining on' or 'constraining off' an interconnector), NEMDE changes the output of generators in adjoining region(s). This does not involve constraining particular generators, rather NEMDE reduces or increases the level of supply that is sourced from interstate generators.

Coefficients in constraint equations

As was noted earlier, the LHS of constraint equations contain all of the inputs that can be varied by NEMDE to avoid violating the constraint, such as output from generators and flow on interconnectors. Each generator or interconnector on the LHS has a coefficient, which reflects the impact it has on the constrained transmission line. In other words, the effect of a one megawatt (MW) change in the output of a particular generator (or flow on a particular interconnector) on flows over the constrained line is reflected in the coefficient assigned in the LHS. For example, if a one MW reduction in output of a generator decreases flow on the constrained line by one MW, the coefficient is +1. A positive coefficient means that a generator may be 'constrained-off' when the constraint binds, while a negative coefficient means a generator is 'constrained-on'. The further away a generator or interconnector is located from the constrained line, the greater the change in output required to achieve a one MW change in flow over the constrained line. This is reflected by a smaller coefficient.

---

10 Constraint equations can be expressed as LHS ≤ RHS or LHS ≥ RHS. For the purposes of this report, the descriptions of constraint equations are limited to LHS ≤ RHS. These are the most common types of constraint equations used to manage network limits.

11 Constraint may stop binding due to for example an increase in line rating (which can be influenced by ambient weather conditions) or changes in generator offers.