



Electricity Pricing Event Reports

MAY 2016

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Sunday 01 May 2016 – Negative Energy price TAS

Market Outcomes: Tasmania had a negative spot price of -\$404.13/MWh for trading interval (TI) ending 0800 hrs.

FCAS prices in Tasmania were elevated for TI ending 0800 hrs, but did not reach the threshold value of \$3,000/MWh for reporting purposes. FCAS and Energy prices for the other NEM regions were not affected by this event.

Detailed Analysis: The 5-Minute dispatch price reduced to below -\$999.00/MWh for dispatch intervals (DIs) ending 0735 hrs, 0745 hrs and 0750 hrs. These negative prices can be attributed to high wind generation, a steep supply curve and the reclassification of transmission lines in Tasmania, while Basslink was out of service.

For the high priced DIs, wind generation in Tasmania was between 149 MW and 162 MW, accounting for at least 20% of Tasmania generation during those intervals. Tasmania generation capacity was offered at less than \$0/MWh or above \$100/MWh, resulting in a steep supply curve.

In response to lightning storms in the area, the loss of the Liapootah – Waddamana Tee Palmerston No. 1 and No. 2 220 kV Lines was declared a credible contingency from 0615 hrs until 0755 hrs (Market Notices no. 52946 and 52979). The reclassification constraint set T-LIPM_N-2 was invoked during this period to manage the possible simultaneous tripping of the lines.

Between DIs ending 0735 and 0755, the binding constraint equation T>T_NIL_LIPM_N-2_2B from the reclassification constraint set T-LIPM_N-2 constrained on up to 212 MW of hydro generation. This constraint equation prevents overload of the Palmerston – Waddamana 110 kV line for the contingent loss of both the Liapootah – Waddamana Tee Palmerston No.1 and No.2 220 kV lines.

The 5-minute price in Tasmania increased to at or above \$100.32/MWh for the DIs subsequent to the negative priced DIs, when demand increased and wind generation decreased. From DI ending 0755 hrs, the constraint equation T_MRWF_ZERO was invoked, which constrain generation at Musselroe wind farm to 0MW, reducing wind generation. This constraint equation is a discretionary 0 MW upper limit on Musselroe Wind Farm.

The negative spot price was not forecast in the latest pre-dispatch schedule, as it was a result of reclassification of transmission lines and changes in wind generation within the affected TI.

Wednesday 04 May 2016 – High Energy price SA

Market Outcomes: South Australia spot price reached \$1,083.81/MWh for trading interval (TI) ending 0000 hrs.

Victorian spot price was negative for the affected TI, but did not reach the price threshold for reporting purposes. FCAS prices in all regions and Energy prices for the other NEM regions were not affected by this event.

Detailed Analysis: 5-Minute dispatch price in South Australia reached \$6,426.40/MWh for dispatch interval (DI) ending 2335 hrs. The high price can be attributed to an increase in demand, during a period of limited interconnector support.

- Between DIs ending 2330 hrs and 2335 hrs, South Australian demand increased by 176MW to 1,526MW, due to hot water load management.



- Low wind generation of 416 MW for TI ending 0000 hrs.
- For DI ending 2335 hrs, target flow on the Heywood interconnector was limited to 346 MW towards South Australia by the voltage stability constraint equation $V^{AS_TBCPTX_MAXG}$. This constraint equation manages voltage stability across the Victoria – South Australia cutset for the loss of the largest generator in South Australia, during an outage of the Tailem Bend 275/132kV transformer and Tailem Bend Capacitor Bank.
- Target flow on the Murraylink interconnector was limited to 57 MW towards Victoria by the $V>>SML_NIL_CONT_7B$ system normal constraint equation. The constraint equation prevents overload of the Buangor – Arrarat 66 kV transmission line for the loss of the Ballarat – Waubra – Horsham 220 kV transmission line.
- Cheaper priced generation was available during the high priced DI, but was constrained off by the binding constraint equation $V^{AS_TBCPTX_MAXG}$ (Lake Bonney Wind Farms 2 and 3), required more than one DI to synchronise (Quarantine PS unit 5), was limited by ramp rates (Torrens Island A units 1 and 3, Torrens Island B units 2 and 4) or was limited by FCAS profiles (Northern PS unit 1).

The 5-minute price in South Australia reduced to \$25.94/MWh, for DI ending 2340 hrs, when:

- 322 MW of generation capacity was rebid from bands priced at or above \$54.99/MWh to the Market Floor Price (MFP) of -\$1,000/MWh.
- Demand decreased by 21MW.

The high 30-minute spot price for South Australia was not forecast in the latest pre-dispatch schedule, as it was a result of a spike in 5-minute demand during the affected TI.

** A summary was prepared as the maximum daily spot price was between \$500/MWh and \$2,000/MWh.*

Thursday 05 May 2016 – High Energy price QLD

Market Outcomes: Spot price in Queensland reached \$2,336.52/MWh for trading interval (TI) ending 0800 hrs.

FCAS prices in all regions and Energy prices for the other NEM regions were not affected by this event.

Detailed Analysis: The 5-minute dispatch price reached \$13,795.00/MWh for Dispatch Interval (DI) ending 0750 hrs. This high price can be attributed to a spike in demand and limited availability of cheaper priced generation.

Between DIs ending 0745 hrs and 0750 hrs, demand in Queensland increased by 108 MW to 6,580 MW.

Since DI ending 0535 hrs, the thermal constraint equation $Q>NIL_BI_FB$ was binding or violating. This constraint equation prevents overloading of feeder bushings at Boyne Island for the contingent loss of one Calliope River to Boyne Island 132 kV line, under system normal conditions. Between DIs ending 0745 hrs and 0750 hrs, flow across the Boyne Island no. 7145 and 7146 132kV lines increased by a total of 26.8 MVA. To prevent the constraint equation from violating, cheaper priced generation from Gladstone PS units 1 – 6 was constrained off further.



Other cheaper priced generation was available, but required more than one DI to synchronise (Braemar PS unit 1) or was ramp rate limited (Oakey GT unit 2, Stanwell PS units 1 and 3, Tarong PS units 2 and 3).

For DI ending 0750 hrs, the target flow towards Queensland on the QNI interconnector was limited to 412 MW towards Queensland by the N^Q_NIL_A constraint equation. This constraint equation prevents voltage collapse in New South Wales for the loss of Liddell – Muswellbrook no. 83 330kV line. The target flow towards Queensland on the Terranora interconnector was limited to 10 MW by the hard ramping constraint #R013963_001_RAMP_F. This ramping constraint was invoked in preparation for a planned concurrent outage of two Directlink cables.

The 5-minute price reduced to \$27.08/MWh for DI ending 0755 hrs, when demand reduced by 340 MW and 272 MW of generation capacity was rebid from the Market Price Cap (MPC) of \$13,800/MWh to the Market Floor Price (MFP) of -\$1,000/MWh.

The high 30-minute spot price for Queensland was not forecast in the pre-dispatch schedules, as it was a result of a spike in demand, during the affected TI.

Monday 09 May 2016 – High FCAS price Mainland

Market Outcomes: The Mainland (Queensland, New South Wales, Victoria and South Australia) had high Raise Regulation Frequency Control Ancillary Service (FCAS) prices, ranging between \$79.00/MWh and \$231.16/MWh for 9 trading intervals (TI) between TIs ending 0800 hrs and 1300 hrs. Fast Raise FCAS price in the Mainland ranged between \$61.21/MWh and \$144.23/MWh for the same intervals.

FCAS and Energy prices in Tasmania were not affected by this event. Energy prices for the Mainland were elevated but did not reach the price threshold for reporting purposes.

Detailed Analysis: The Raise Regulation FCAS prices in the Mainland were above \$100/MWh for 33 dispatch intervals (DIs) between DIs ending 0755 hrs and 1255 hrs. The Fast Raise FCAS prices in the Mainland were above \$100/MWh for 31 DIs between DIs ending 0800 hrs and 1255 hrs. These high FCAS prices can be mainly attributed to increased FCAS requirements on the Mainland, due to a reduction in wind generation in South Australia, planned generator outages, limited availability of cheaper priced FCAS capacity and steep supply curves in the Raise Regulation and Fast Raise FCAS markets. In addition, FCAS support from Tasmania was unavailable due to the outage of the Basslink interconnector from 20 December 2015.

Since early April 2016, there has been limited availability of cheaper priced Raise Regulation and Fast Raise FCAS capacity across the Mainland. Several generating units that typically provide cheaper priced Raise Regulation and Fast Raise FCAS capacity were unavailable for extended periods. These include, Bayswater PS Unit 2, Vales Point PS Unit 6, Torrens Island PS A Units 1 – 4 and Torrens Island PS B Unit 2. Additionally, on 9 May 2016, Stanwell PS Unit 1 was unavailable until 1305 hrs.

During the high priced TIs, wind generation steadily reduced across South Australia from 1055 MW, for TI ending 0800 hrs, to 505 MW, for TI ending 1300 hrs. Some wind farms in South Australia experienced high wind speeds during this period, resulting in high wind speed cut-out of wind turbines. This reduced the generation output from the wind farms and contributed to an increase in the accumulated time error in the mainland.



The accumulated time error in the Mainland was below -1.5 sec for 97 minutes between 0951 hrs and 1238 hrs. To manage the time error, the amount of Raise Regulation services enabled in the Mainland increased from 180 MW for DI ending 0950 hrs to 244 MW (maximum) for DI ending 1055 hrs.

Between DIs ending 0705 hrs and 0735 hrs, 240 MW of Fast Raise (Wivenhoe PS No.2 Pump) and 60 MW of Raise Regulation (Stanwell PS Units 2 and 3) FCAS capacity was withdrawn by CS Energy and Stanwell respectively. The reasons submitted were '1501P FCAS ENABLEMENT UPDATE-SL' (CS Energy) and '0724P MANAGE PORTFOLIO SPS1 TRIP SL' (Stanwell). For DI ending 0835 hrs, IPM Australia withdrew a total of 135 MW of Loy Yang B PS Unit 2 generation capacity from the Raise Regulation and Fast Raise FCAS markets with the reason '0822P UPDATE AVAIL: UNIT GOING OOS - TUBE LEAK'. For the same DI, 300 MW of Loy Yang B PS Unit 2 generation capacity was also withdrawn from the Energy market with the same reason.

A number of units providing cheaper priced FCAS in the Mainland were dispatched close to their maximum capacity in the energy market, which effectively reduced their Fast Raise and Raise Regulation FCAS availability. For the high priced DIs, 5-minute energy prices were elevated to between \$124.90/MWh and \$480.20/MWh across the Mainland regions.

Between DIs ending 0850 hrs and 0855 hrs, Mainland demand increased by 109 MW. Thus, additional generation capacity was dispatched in the energy market, further reducing the availability in the Fast Raise and Raise regulation markets for that period.

The Mainland FCAS prices for Raise Regulation and Fast Raise Services reduced to \$22.47/MWh and \$16.91/MWh, respectively, for DI ending 1300 hrs, when the time error in the Mainland had recovered, 320 MW of generation capacity was rebid in the energy market from bands priced at or above \$299.99/MWh to bands priced at or below \$0/MWh and availability of Fast Raise and Raise Regulation capacity increased.

The high 30-minute Mainland FCAS prices for all affected TIs (except TIs ending 0800 hrs and 1300 hrs) were forecast in the pre-dispatch schedules.

Tuesday 17 May 2016 – High Energy price SA

Market Outcomes: South Australian spot price reached \$1,126.17/MWh, \$2,062.18/MWh, \$1,949.43/MWh and \$1,860.31/MWh for trading intervals (TI) ending 0830 hrs, 1830 hrs, 1930 hrs and 0000 hrs, respectively.

FCAS prices for all regions and Energy prices for the other NEM regions were not affected by this event.

Detailed Analysis: 5-Minute dispatch price in South Australia reached \$6,480.90/MWh for dispatch interval (DI) ending 0810 hrs and reached \$10,758.59/MWh for all three DIs ending 1830 hrs, 1915 hrs and 2335 hrs. These high prices can be attributed to a steep supply curve and low wind generation during a period of limited interconnector support.

Planned outage of the Cherry Gardens – Tailem Bend 275kV lines was scheduled between 0838 hrs on 17 May 2016 and 1630 hrs on 20 May 2016. Various ramping constraints were invoked between DIs ending 0800 hrs and 0900 hrs to prepare for the outage. The ramping constraints violated for DI ending 0810 hrs.



Between DIs ending 0800 hrs to 0810 hrs, the soft ramping constraint #R014008_006_RAMP_V forced the target flow across the Heywood interconnector to reverse from 191MW towards South Australia to 12 MW towards Victoria. The target flow on the Murraylink interconnector was limited to 220 MW towards South Australia by the upper transfer limit constraint equation, VSML_220. For the same DI, cheaper priced generation was available but was limited due to ramp rates (Torrens Island A units 1, 2 and 4, Torrens Island B units 3 and 4) or fast start profiles (Dry Creek unit 3).

During the high priced TIs, between 1830 hrs and 0000 hrs, wind generation in South Australia was low, between 63 MW and 65 MW. For all DIs between 1830hrs and 0000hrs, the target flow on the Heywood interconnector was limited up to 19 MW towards South Australia by the thermal constraint equation $S \gg X_{TB-EBUS+CGTB_3}$. This constraint equation prevents the overload of the Tailem Bend – Mobiong no.1 132kV line for the loss of the South East – Tailem Bend no.2 275kV line, during the outage of the Cherry Gardens – Tailem Bend 275kV line, Tailem Bend 275kV East Bus and Tailem Bend circuit breakers no.6535 and 6536

For DI ending 1915 hrs, Snowy Hydro rebid 63 MW of generation capacity from the \$0/MWh to \$13,745/MWh.

For DIs ending 1830 hrs and 1915 hrs, target flow on the Heywood interconnector was limited up to 48 MW, towards South Australia by the thermal constraint equation $S \gg X_{TB-EBUS+CGTB_3}$. For the same DIs, cheaper priced generation was available, but was limited due to ramp rates (Dry Creek CGT unit 3).

Between DIs ending 2330 hrs and 2335 hrs, South Australian demand increased by 183MW to 1,530MW, due to hot water load management. For the high priced DI ending 2335 hrs, target flow on the Heywood interconnector was limited to 19 MW towards South Australia by the thermal constraint equation $S \gg X_{TB-EBUS+CGTB_3}$.

The 5-minute price in South Australia reduced to at or below \$296.58/MWh for the DIs subsequent to the high priced DIs, when up to 680 MW of generation capacity was rebid from bands priced at or above \$64.98/MWh to bands priced at or below -\$991.08/MWh.

The high 30-minute spot prices for South Australia were not forecast in the latest pre-dispatch schedules, as it was a result of rebidding within the affected TI (TI ending 1930 hrs), implementation of pre-ramping constraints in the dispatch run (TI ending 0830 hrs) and the different formulation of constraints between pre-dispatch and dispatch (TIs ending 0830 hrs, 1830 hrs and 1930 hrs).

Wednesday 18 May 2016 – High Energy price SA, Negative Energy price VIC

Market Outcomes: Spot price was \$1,175.46/MWh in South Australia and -\$142.28/MWh in Victoria for trading interval (TI) ending 0000 hrs.

FCAS prices in all regions and Energy prices for the other NEM regions were not affected by this event.

Counter price flows caused negative settlement residues of approximately \$213,000 to accumulate on the South Australia to Victoria directional interconnector for TIs ending 0000 hrs and 0030 hrs. AEMO managed negative residues from 2340 hrs to 0100 hrs (Market Notices 53406 and 53407).



Detailed Analysis: 5-Minute dispatch price was \$10,781/MWh in South Australia and -\$898.85/MWh in Victoria for dispatch interval (DI) ending 2335 hrs. The high South Australian price and negative Victorian price can be mainly attributed to a spike in South Australian demand and resulting changes to interconnector flows, during the outage of the Cherry Gardens – Tailem Bend 275kV line.

Between DIs ending 2330 hrs and 2335 hrs, South Australian demand increased by 168MW, due to hot water load management. Wind generation in South Australia was moderate, at 436 MW, for TI ending 0000 hrs.

During the same period, target flow on the Heywood interconnector reversed from 117 MW towards Victoria to 7 MW towards South Australia. Over this period, the Heywood interconnector was limited by the thermal constraint equation, $S \gg X_CGTB+TB35+36_13$. This constraint equation prevents the overload of the Snuggery – Keith 132kV line for the loss of the South East – Tailem Bend no.2 275kV line, during the outage of the Cherry Gardens – Tailem Bend 275kV line and Tailem Bend 275kV circuit breakers no.6536 and no.6535.

The target flow on the Murraylink interconnector reversed from 60 MW towards Victoria to 4 MW towards South Australia and the target flow on the VIC-NSW interconnector reduced from 633 MW to 132 MW towards New South Wales. For these DIs, both interconnectors were limited by the thermal constraint equation, $V \gg SML_NIL_CONT_7B$. This constraint equation prevents the overload of the Buangor – Arrarat 66kV line for the loss of the Ballarat – Waubra – Horsham 220kV line, under system normal conditions. These interconnector flow changes resulted in excess availability of cheaper priced generation capacity within Victoria, which caused the price to collapse to -\$898.85/MWh for DI ending 2335 hrs.

Cheaper priced generation was available in South Australia, but was constrained off by the thermal constraint equation $S \gg X_CGTB+TB35+36_13$ (Ladbroke PS, Lake Bonney 2 WF and Lake Bonney 3 WF).

Due to the counter-price flow on the South Australia to Victoria directional interconnector, the Negative Settlement Residue Management (NRM) constraint equation NRM_SA1_VIC1 was invoked between DIs ending 2345 hrs and 0045 hrs. A spike in demand followed by rebidding to the MPF in South Australia, during this period, caused the flows on Heywood interconnector to change direction rapidly, resulting in intervals when negative residues accumulated. The NRM constraint equation bound for 11 DIs during this period.

The 5-minute price reduced to \$30.70/MWh in South Australia and increased to \$31.99/MWh in Victoria, for DI ending 2340 hrs, when 168 MW of generation capacity was rebid in South Australia from bands priced at or above \$10,781.81/MWh to the Market Floor Price (MFP) of -\$1,000/MWh.

The high 30-minute spot price for South Australia and low 30-minute price for Victoria were not forecast in the latest pre-dispatch schedule, due to different formulation of the thermal constraint equation, $S \gg X_CGTB+TB35+36_13$, in pre-dispatch and dispatch.

Saturday 21 May 2016 – High FCAS price Mainland



Market Outcomes: The Mainland (Queensland, New South Wales, Victoria and South Australia) had high Delayed Raise Frequency Control Ancillary Service (FCAS) and Raise Regulation FCAS prices, ranging between \$49.85/MWh and \$112.43/MWh for 3 trading intervals (TIs) between TIs ending 1730 hrs and 1830 hrs. The Fast Raise FCAS price in the Mainland ranged between \$28.78/MWh and \$79.94/MWh for the same intervals.

FCAS and Energy prices in Tasmania were not affected by this event. Energy prices for the Mainland were elevated but did not reach the price threshold for reporting purposes.

Detailed Analysis: The 5-minute Delayed Raise and Raise Regulation FCAS prices in the Mainland ranged between \$49.20/MWh and \$197.58/MWh between dispatch intervals (DIs) ending 1705 hrs and 1815 hrs. The 5-minute Fast Raise FCAS prices in the Mainland ranged between \$34.20/MWh and \$99.46/MWh for the same DIs. These high FCAS prices can be mainly attributed to the withdrawal and rebidding of generation capacity from the FCAS markets, steep supply curves in the FCAS markets and increased demand during the afternoon peak period. In addition, FCAS support from Tasmania was unavailable due to the outage of the Basslink interconnector from 20 December 2015.

Since early April 2016, there has been limited availability of cheaper priced Raise Regulation, Delayed Raise and Fast Raise FCAS capacity across the Mainland. Several generating units that typically provide cheaper priced Raise Services were unavailable for extended periods. These include, Bayswater PS Unit 2, Vales Point PS Unit 6, Gladstone PS Unit 2, Torrens Island PS A Units 1 – 4 and Torrens Island PS B Unit 2.

For DI ending 1705, 240 MW of Delayed Raise (Tumut 3 PS) FCAS capacity was withdrawn by Snowy Hydro with the reason '16:02 A NSW: 30MPD PRICE \$195.07 HGR THN 30MPD 16:50@15:32'.

For DI ending 1735 hrs, Delta shifted 15 MW of Delayed Raise FCAS capacity from bands priced at or below \$30.37/MWh to bands priced at \$101.25/MWh. For the same DI, Delta shifted 20 MW of Raise Regulation FCAS capacity from bands priced at or below \$15.19/MWh to bands priced at \$13,971.85/MWh.

A number of units providing cheaper priced FCAS in the Mainland were dispatched close to or at their maximum capacity in the energy market, which effectively reduced their Raise FCAS availability.

Between DIs ending 1705 hrs and 1800 hrs, Mainland demand increased by 1,278MW. Thus, additional generation capacity was dispatched in the energy market, which further reduced the Fast Raise, Delayed Raise and Raise Regulation availability during this period. For the high priced DIs, 5-minute energy prices were elevated up to \$299.80/MWh across the Mainland regions. The energy prices impacted the FCAS prices, as the Raise FCAS availability was adjusted against the energy dispatch. In addition, Raise Regulation was dispatched to substitute for expensive Delayed Raise.

The Mainland FCAS prices for Fast Raise, Delayed Raise and Raise Regulation Services reduced to \$30.00/MWh, \$30.00/MWh and \$20.80/MWh, respectively, for DI ending 1820 hrs, when the Mainland demand reduced by 92 MW and Fast Raise, Delayed Raise and Raise Regulation availability increased.

The high 30-minute Mainland FCAS prices were forecast in the pre-dispatch schedules.



Sunday 22 May 2016 – High FCAS price Mainland

Market Outcomes: The Mainland (Queensland, New South Wales, Victoria and South Australia) had high Delayed Raise Frequency Control Ancillary Service (FCAS) and Raise Regulation FCAS prices, both reaching \$83.25/MWh for trading interval (TI) ending 1800 hrs and \$78.94/MWh for TI ending 1830 hrs.

FCAS and Energy prices in Tasmania were not affected by this event. Energy prices for the Mainland were elevated but did not reach the price threshold for reporting purposes.

Detailed Analysis: The 5-minute Raise Regulation and Delayed Raise FCAS prices in the Mainland were above \$75.00/MWh for 8 dispatch intervals (DIs) between DIs ending 1740 hrs and 1815 hrs. These high FCAS prices can be mainly attributed to increased Delayed Raise FCAS requirements on the Mainland, planned generator outages, limited availability of cheaper priced FCAS capacity, a steep supply curve in the FCAS markets and increased demand during the afternoon peak period. In addition, FCAS support from Tasmania was unavailable due to the outage of the Basslink interconnector from 20 December 2015.

Since early April 2016, there has been limited availability of cheaper priced Raise Regulation FCAS capacity across the Mainland. Several generating units that typically provide cheaper priced Raise Regulation were unavailable for extended periods. These include, Bayswater PS Unit 2, Vales Point PS Unit 6, Torrens Island PS A Units 1 – 4 and Torrens Island PS B Unit 2.

For DI ending 1705 hrs, Snowy Hydro withdrew 240 MW of Delayed Raise capacity from Tumut 3 PS with the reason '16:32 A NSW: 30MPD PRICE \$164.05 HGR THN 30MPD 17:30@16:02'.

For DI ending 1735 hrs, Delta shifted 15MW of Delayed Raise FCAS capacity from bands priced at or below \$30.37/MWh to bands priced at or above \$101.25/MWh. For the same DI, Delta shifted 25 MW of Raise Regulation capacity from bands priced at or below \$101.25/MWh to bands priced at \$13,971.85/MWh.

A number of units providing cheaper priced FCAS in the Mainland were dispatched close to or at their maximum capacity in the energy market, which effectively reduced their Raise FCAS availability.

Between TIs ending 1730 hrs and 1830 hrs, Mainland operational demand increased by 1,030 MW, reaching a maximum of 22,640 MW for TI ending 1830 hrs. Thus, additional generation capacity was dispatched in the energy market, which further reduced the Delayed Raise and Raise Regulation availability during this period. For the high priced DIs, 5-minute energy prices were elevated up to \$307.06/MWh across the Mainland regions. The energy prices impacted the FCAS prices as the Raise FCAS availability was adjusted against the energy dispatch. In addition, Raise Regulation was dispatched to substitute for expensive Delayed Raise.

The Mainland FCAS prices for Raise Regulation and Delayed Raise Services both reduced to \$59.65/MWh, for DI ending 1820 hrs, when Mainland demand decreased by 165 MW and Delayed Raise availability increased.

The high 30-minute Mainland FCAS prices were forecast in the pre-dispatch schedules.



Monday 23 May 2016 – Negative Energy price SA, VIC, High Energy price SA

Market Outcomes: Spot prices in South Australia ranged between $-\$140.99/\text{MWh}$ and $-\$368.47/\text{MWh}$ for 6 trading intervals (TIs) between TIs ending 0130 hrs and 0500 hrs. Spot prices in Victoria ranged between $-\$188.59/\text{MWh}$ and $-\$517.12/\text{MWh}$ for the same TIs. The spot price in South Australia reached $\$2,149.77$ for trading interval (TI) ending 0900 hrs.

Energy prices in other NEM regions and FCAS prices were not affected by this event

Detailed Analysis: The 5-Minute dispatch price in South Australia ranged between $-\$326.43/\text{MWh}$ and the Market Floor Price (MFP) of $-\$1,000/\text{MWh}$ for 23 dispatch intervals (DIs) between DIs ending 0115 hrs and 0500 hrs. The 5-minute dispatch in Victoria price ranged between $-\$474.24/\text{MWh}$ and $-\$896.49/\text{MWh}$ for the same DIs. These negative prices can be mainly attributed to the reduced rating on the South Morang F2 500/330kV transformer and subsequent implementation of constraint automation equations to prevent the overload on the transformer.

An unplanned outage of APD Potline 1 at 2354 hrs on 22 May 2016 caused the South Morang F2 500/330 kV transformer loading to increase to 1,116 MVA at 2358 hrs. At 0002 hrs on 23 May, AusNet advised AEMO that the South Morang F2 500/330 kV transformer loading had exceeded its short term rating of 1100 MVA. To prevent damage to the transformer, AusNet advised AEMO the transformer loading should not exceed 1,000 MVA for the next 24 hrs (Market Notice 53461). Thus, AEMO amended the short term ratings on the transformer to 1000 MVA. At 0010 hrs on 23 May 2016, APD Potline 1 returned to service.

At 0105 hrs, real time contingency analysis (RTCA) indicated that under pre-existing constraints, the South Morang F2 500/330 kV transformer would overload for the loss of the APD potlines with either of the Heywood – Tarrone No.1 500 kV line or the Heywood – Mortlake No.2 500 kV line.

As no pre-formulated constraint equations were available, constraint automation was used to build the constraint equations, CA_SPS_46545836_01 and CA_SPS_46545836_02. These constraint equations were invoked between 0110 hrs and 0930 hrs (Market Notice 53465 and 53502) to prevent overload of the F2 transformer as indicated by RTCA.

The constraint equations, CA_SPS_46545836_01 and CA_SPS_46545836_02, reduced flow towards New South Wales across the VIC-NSW interconnector and increased flow towards South Australia across the VIC-SA interconnector. The target flow towards New South Wales across the VIC-NSW interconnector reduced from 945 MW, for DI ending 0110 hrs, to 112 MW for DI ending 0440 hrs. The target flow towards South Australia across the Heywood interconnector increased from 201 MW, for DI ending 0110 hrs, to 550 MW towards South Australia for DI ending 0440 hrs.

As a result, the flow across the South Morang F2 500/330 kV transformer decreased steadily from 910 MVA at DI ending 0105 hrs to 354 MVA (minimum) at 0440 hrs.

For the negative priced TIs, demand was low in South Australia and Victoria, reaching a minimum of 1,167 MW and 3,861 MW, respectively.

With excess cheaper priced generation available in Victoria and South Australia, prices in these regions collapsed to at or below $-\$326.43/\text{MWh}$ for the affected DIs between 0115 hrs and 0500 hrs.



Victoria and South Australia returned to positive prices at DIs ending 0550 hrs and 0620 hrs, respectively, when the loading on the South Morang F2 500/330kV transformer increased and demand in both regions increased.

The 5-minute dispatch price in South Australia reached \$12,195.07/MWh for DI ending 0855 hrs. This high price can be attributed to the withdrawal of generation capacity, a steep supply curve and an increase in demand, during a period of limited interconnector support, which resulted from the implementation of constraint automation equations.

Between DIs ending 0850 hrs and 0855 hrs, demand in South Australia increased by 44 MW and wind generation decreased by 43 MW. For DI ending 0855 hrs, generation capacity in South Australia was offered in bands priced below \$65/MWh or above \$12,195/MWh, resulting in a steep supply curve.

Between DIs ending 0835 hrs and 0855 hrs, AGL withdrew 310 MW of generation capacity from Torrens Island B Units 3 and 4 with the reasons '0825~P~010 UNEXPECTED/PLANT LIMITS~106 AUX/PLANT FAILURE', '0830~P~030 INCREASE IN AVAIL CAP~UNIT REMAINING ON LOAD' and '0845~P~020 REDUCTION IN AVAIL CAP~204 UNIT TRIP'.

For DI ending 0855 hrs, target flow on the Heywood interconnector was limited to 370 MW towards South Australia by the constraint automation equation, CA_SPS_46545836_02, transient stability constraint equation, V::S_NIL_TBSE, and thermal constraint equation, V>>S_NIL_SETB_SGKH. The target flow on the Murraylink interconnector was limited to 220 MW towards South Australia by the upper limit transfer constraint equation, VSML_220.

Cheaper priced generation was available but limited due to ramp rates (Osborne PS), fast start profiles (Hallett PS, Ladbroke Grove PS Units 1 and 2) or constrained off by the constraint equations, V::S_NIL_TBSE and V>>S_NIL_SETB_SGKH (Lake Bonney Windfarm units 2 and 3).

The 5-minute price in South Australia decreased to \$41.77/MWh for DI ending 0900 hrs, when 177 MW of generation capacity was rebid from bands priced at or above \$13,676.91/MWh to bands priced at or below -\$991.08/MWh and demand decreased by 51 MW.

At 0930 hrs, AEMO applied continuous rating of 850 MVA to the South Morang F2 500/330 kV transformer and revoked the constraint equations CA_SPS_46545836_01 and CA_SPS_46545836_02. The short term rating remained at 1,000 MVA. At 0002 hrs on Tuesday 24 May 2016, the transformer ratings were returned to normal. (Market Notices 53503 and 53505)

The spot prices, between TIs ending 0130 hrs and 0500 hrs, forecast for South Australia and Victoria in the latest pre-dispatch schedules were negative, but much smaller in magnitude than the dispatch prices. This difference was a result of the different formulation of the constraint equations, CA_SPS_46545836_01 and CA_SPS_46545836_02, in pre-dispatch and dispatch. The high spot price for TI ending 0900 hrs for South Australia was not forecast in the latest pre-dispatch schedule, as it was the result of withdrawal of generation capacity within the affected TI and different formulation of the constraint equation, CA_SPS_46545836_02, in pre-dispatch and dispatch.

Tuesday 24 May 2016 – High FCAS price Mainland

Market Outcomes: The Mainland (Queensland, New South Wales, Victoria and South Australia) had high Delayed Raise and Raise Regulation Frequency Control Ancillary Service (FCAS) prices, reaching \$59.07/MWh and \$69.83/MWh, respectively, for trading interval (TI) ending 0830 hrs.



FCAS and Energy prices in Tasmania were not affected by this event. Energy prices for the Mainland were elevated but did not reach the price threshold for reporting purposes.

Detailed Analysis: The 5-minute Delayed Raise and Raise Regulation FCAS prices in the Mainland were both \$254.50/MWh for dispatch interval (DI) ending 0810 hrs. These high FCAS prices can be mainly attributed to withdrawal of generation capacity from the Delayed Raise and Raise Regulation FCAS markets, limited availability of cheaper priced FCAS capacity, increased demand during the morning peak period and steep supply curves in the FCAS markets. In addition, FCAS support from Tasmania was unavailable due to the outage of the Basslink interconnector from 20 December 2015.

Since early April 2016, there has been limited availability of cheaper priced Raise Regulation and Delayed Raise FCAS capacity across the Mainland. Several generating units that typically provide cheaper priced Raise Regulation and Delayed Raise FCAS capacity were unavailable for extended periods. These include, Bayswater PS Unit 2, Vales Point PS Unit 6, Torrens Island PS A Units 1 – 4 and Torrens Island PS B Unit 2.

For DI ending 0705 hrs, 480 MW of Delayed Raise FCAS capacity were withdrawn by Snowy Hydro (Tumut PS) and CS Energy (Wivenhoe PS No.2 Pump). The reasons submitted were '15:02:P UPDATE AVAIL FOR CHANGE TO OUTAGE PLAN/PLANT CONDITIONS' and '1434A DAILY OFFER', respectively.

For DI ending 0805 hrs, Eraring rebid 10 MW of Raise Regulation capacity from \$0.01/MWh to \$14,001.61/MWh.

A number of units providing cheaper priced FCAS in the Mainland were dispatched close to their maximum capacity in the energy market, which effectively reduced their Raise FCAS availability.

During the peak morning demand, between DIs ending 0805 hrs and 0810 hrs, Mainland total demand increased by 56 MW. Thus, additional generation capacity was dispatched in the energy market, further reducing the availability in the Delayed Raise and Raise Regulation markets for that period. For DI ending 0810 hrs, 5-minute energy prices were elevated to between \$295.20/MWh and \$351.09/MWh across the Mainland regions. This energy price impacted the FCAS prices as the Raise FCAS availability was adjusted against the energy dispatch. In addition, Raise Regulation was dispatched to substitute for expensive Delayed Raise. The Raise Regulation and Delayed Raise price of \$254.50/MWh was the result of the co-optimisation between Energy and FCAS markets.

The Mainland FCAS prices for Delayed Raise and Raise Regulation Services reduced to \$29.95/MWh and \$30.80/MWh, respectively, for DI ending 0815 hrs, when Mainland demand decreased by 52MW and availability of Delayed Raise capacity increased, mainly from Wivenhoe PS Unit 2. Delayed Raise availability from Wivenhoe PS Unit 2 increased from 0MW to 210MW when the unit's dispatch target was reduced from 250MW to 40MW due to rebidding in the energy market (rebidding effective in DI ending 0810 hrs) and the unit was no longer stranded from DI ending 0815 hrs.

The high 30-minute Mainland FCAS price was forecast in the latest pre-dispatch schedules.

Monday 30 May 2016 – High FCAS price Mainland

Market Outcomes: The Mainland (Queensland, New South Wales, Victoria and South Australia) had high Delayed Raise and Raise Regulation Frequency Control Ancillary Service (FCAS) prices, ranging between \$86.75/MWh and \$146.46/MWh, between trading intervals (TIs) ending 1730 hrs and 1830



hrs. The Fast Raise FCAS price in the Mainland ranged between \$29.49/MWh and \$34.20/MWh for the same intervals.

FCAS and Energy prices in Tasmania were not affected by this event. Energy prices for the Mainland were elevated but did not reach the price threshold for reporting purposes.

Detailed Analysis: The 5-minute Delayed Raise and Raise Regulation FCAS prices in the Mainland ranged between \$61.13/MWh and \$267.63/MWh between dispatch intervals (DIs) ending 1705 hrs and 1830 hrs. The 5-minute Fast Raise FCAS prices in the Mainland ranged between \$17.72/MWh and \$38.00/MWh for the same DIs. These high FCAS prices can be mainly attributed to increased Regulation FCAS requirements on the Mainland due to an increasing time error. Other contributing factors include, rebidding of generation capacity from the Delayed Raise and Fast Raise FCAS markets, limited availability of cheaper priced FCAS capacity and steep supply curves in the FCAS markets. In addition, FCAS support from Tasmania was unavailable due to the outage of the Basslink interconnector from 20 December 2015.

Since early April 2016, there has been limited availability of cheaper priced Raise Regulation and Delayed Raise FCAS capacity across the Mainland. Several generating units that typically provide cheaper priced Raise Regulation and Delayed Raise FCAS capacity were unavailable for extended periods. These include, Bayswater PS Unit 2, Vales Point PS Unit 6 and Torrens Island PS B Unit 2.

Wind generation decreased in South Australia steadily throughout the day, from 958 MW at TI ending 1100 hrs to 590 MW at 1700 hrs. As wind generation decreased and NEM demand increased in the afternoon, the accumulated time error in the Mainland fell below -1.5 sec between DIs ending 1620 hrs and 1755 hrs. To manage the time error, the amount of Raise Regulation services enabled in the Mainland were elevated above the base requirement of 130 MW between DIs ending 1620 hrs and 1800 hrs. Raise Regulation requirements reached a maximum of 220 MW at DI ending 1740 hrs. The additional Raise Regulation had to be sourced from more expensive units.

A number of units providing cheaper priced FCAS in the Mainland were dispatched close to their maximum capacity in the energy market, which effectively reduced their Raise FCAS availability.

During the peak afternoon demand, between DIs ending 1705 hrs and 1830 hrs, Mainland total demand increased by 1,557 MW. Thus, additional generation capacity was dispatched in the energy market, further reducing the availability in the Raise FCAS markets for that period.

Between DIs ending 1710 hrs and 1830 hrs, 5-minute energy prices were elevated to between \$126.93/MWh and \$313.79/MWh across the Mainland regions. These energy prices impacted the FCAS prices as the Raise FCAS availability was adjusted against the energy dispatch. In addition, between DIs ending 1750 hrs and 1830 hrs, Raise Regulation was dispatched to substitute for expensive Delayed Raise.

For DI ending 1705 hrs, Energy Australia and CS Energy shifted up to 80 MW of Raise FCAS capacity from bands priced at or below \$15.38/MWh to bands priced at or above \$102.52/MWh.

The Mainland FCAS prices for Delayed Raise, Raise Regulation and Fast Raise Services reduced to \$30.80/MWh, \$30.80/MWh and \$25.80/MWh for DI ending 1850 hrs, when Mainland demand decreased by 75 MW and Raise FCAS availability increased.

The high 30-minute Mainland FCAS price was forecast in the latest pre-dispatch schedules.