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Wind Energy - Penetration and Spot Revenue

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Introduction

In our previous article "*Wind Energy – How Much is Enough?*" the authors explored some issues associated with the increasing penetration of wind energy in a thermal power system such as the South Australian region of the National Electricity Market (NEM). In particular, we argued that the diversification introduced by new wind farms may not be substantial, in which case the average electricity spot price earned by the wind generation sector could be expected to decline relative to the (time-weighted) average spot price as additional wind farms are added.

In this paper, we revisit the topic a year later by investigating actual market outcomes. We are concerned with the prospect of uncovering the relationship between the average electricity spot price received by wind farms as a ratio of the time-weighted electricity spot price. We do this by first justifying, and then applying a data adjustment procedure based on capping and renormalisation. In the appendix we look at two particular days characterised by low daily average spot prices and investigate the contribution of high wind generation in interaction with low demand and interconnector constraints to these outcomes.

Wind Penetration in South Australia

South Australia is the NEM region that has experienced the greatest increase in wind energy penetration. Stimulated by the Renewable Energy Target (RET) and the prospect of additional stimulus by means of carbon cost uplifted wholesale electricity prices, wind penetration as a proportion of total regional generation has increased from 6% in 2006 to 17% in 2010 (shown in Table 1).

Table 1 Wind Penetration in South Australia

	Total Generation –SA - (GWh)	Wind Generation – SA - (GWh)	Wind penetration as a % of SA Generation
2006	11,553	714	6.2%
2007	14,310	1,057	7.4%
2008	14,414	1,807	12.5%
2009	13,976	2,334	16.7%
2010 (up to October)	11,617	2,001	17.2%

As a result of increasing wind generation, of all NEM regions, South Australia experiences the greatest number of dispatch intervals with negative prices. Figure

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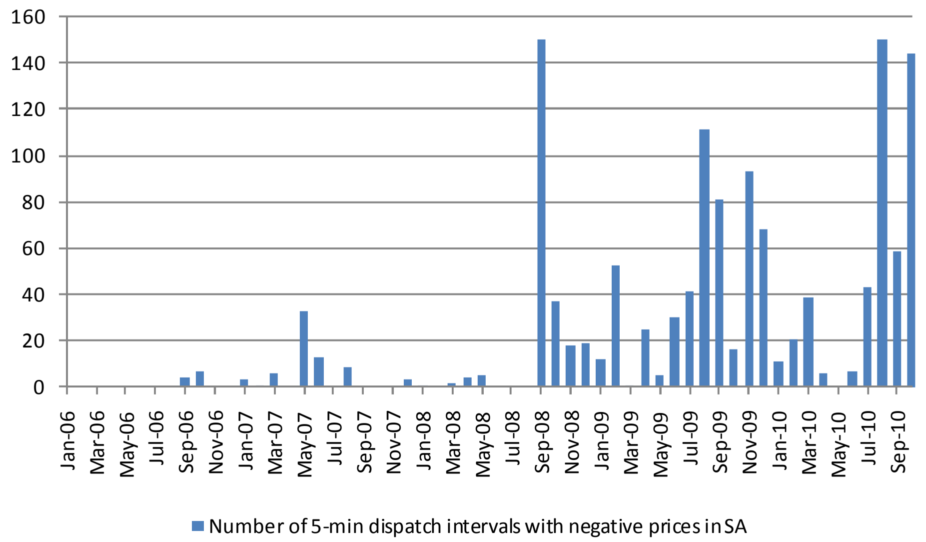
1 shows on a monthly basis since 2006, the number of negatively priced 5 minutes dispatch intervals in that region. Until September 2008, negative prices were rare but became more common as wind penetration increased.

Figure 1 Number of Negatively Priced Dispatch Intervals



Negatively priced dispatch intervals are indicative of an excess generation condition. Broadly this condition occurs when the sum of the minimum generation levels of committed thermal plant, and intermittent generation (largely wind generation) exceeds regional demand and export capacity. The preparedness of particular plants to continue generating at negative prices is a consequence of either their lack of operational flexibility or in the case of wind farms, we suspect it is related to contractual or portfolio obligations.

Assuming some positive correlation between individual wind farms, increasing aggregate wind generation has the potential to result in low spot prices when the aggregate wind generation is high, and high spot prices when the aggregate wind generation is low.

Based on our analysis, as wind energy penetration in South Australia has increased, high wind generation has evidently contributed to low spot prices but it is not evident that low wind generation has led to very high spot prices - at least not at the current wind energy penetration level.

Analysis

A comparison of the South Australian average spot price (TWP) with the aggregate wind generation Dispatch Weighted Price[i] (Wind DWP) from 2006 to 2010 is provided in Table 2 and Figure 2.

[i] The dispatch weighted price is average price a generator can be expected to earn for its generation. It can be calculated as the sum of revenues divided by its generation.

Table 2	SA Average Spot Price and Wind Dispatch Weighted Price ($/MWh)

Year	TWP ($/MWh)	Wind DWP ($/MWh)	DWP Discount ($/MWh)	DWP Discount as a % of the TWP
2006	38.68	34.00	4.68	12.1%
2007	57.49	54.88	2.61	4.5%
2008	66.38	50.20	16.18	24.4%
2009	60.48	50.72	9.76	16.1%
2010	44.33	37.85	6.48	14.6%

Figure 2 Wind DWP discount with respect to the South Australian TWP, expressed in $/MWh and as a % of the TWP

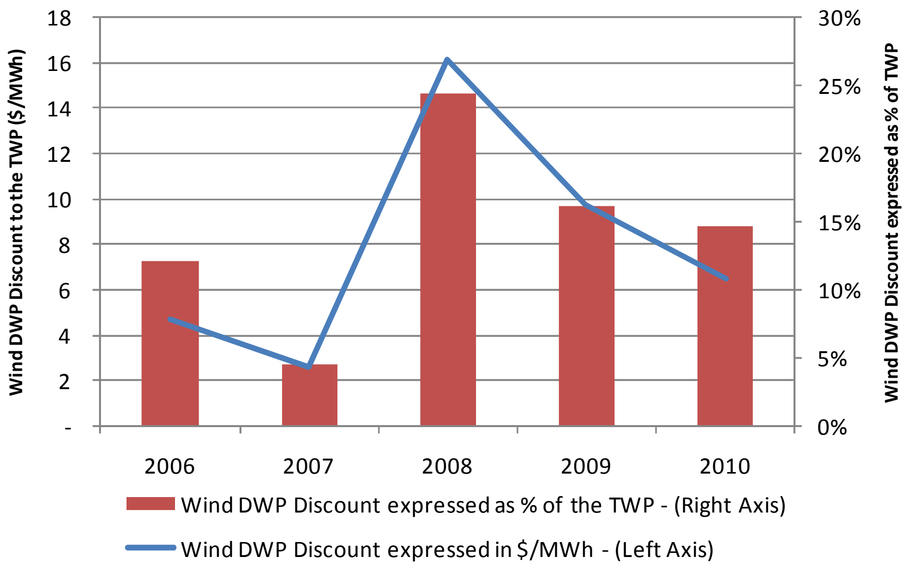
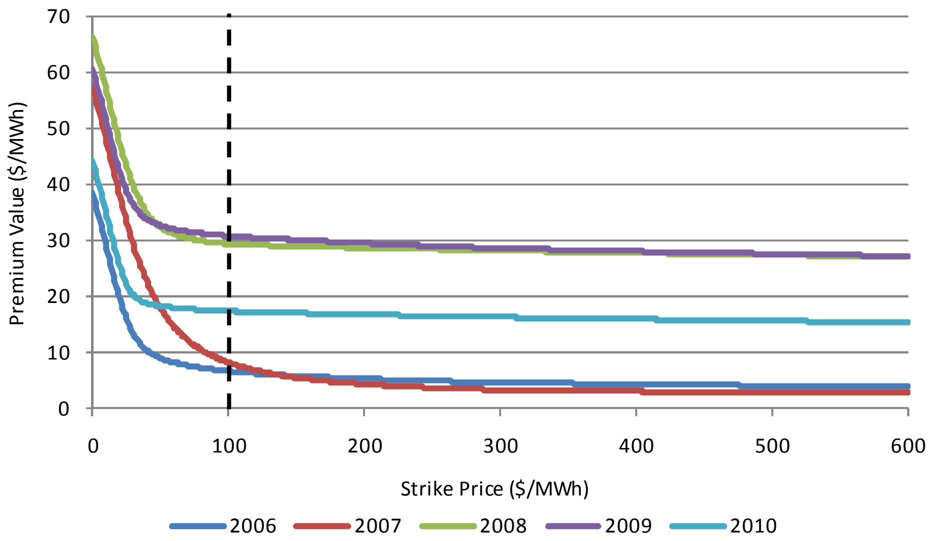


Figure 2 shows that the average price earned by wind farms is at a discount to the TWP. However this discount is highly variable on an annual basis. In 2007, the wind generation sector earned on average 5% less than the average spot price. A year later, the discount moved up to 25%. In 2010 it was back to 10%. On the basis of Figure 2, it is difficult to discern a consistent trend of increasing discount with increasing wind energy penetration. However we believe that by making suitable and appropriate adjustments to data, such a trend can be uncovered.

The basis of our adjustment is to recognise that the distribution of spot prices is in fact a mixture of two distributions each characterised by a market supply related condition. For most of the time, the market is amply supplied and spot price outcomes are determined by vigorous competition. For the rest of the time, supply is relatively short and outcomes are less competitive. Our approach is to consider the correlation of aggregate wind generation with spot price separately for each of these conditions. The choice of the cut-off spot price can be informed by analysing the South Australian premium curves obtained from a standard analysis such as that performed by the IES proprietary data-viewing tool NEO and shown in Figure

3 below. A premium curve identifies the contribution to the annual average spot price for all prices above a specified strike price. For example at a strike price of $100/MWh, the contribution from prices above the strike price to the average annual spot price was around $30/MWh in 2008 and $18/MWh in 2010.

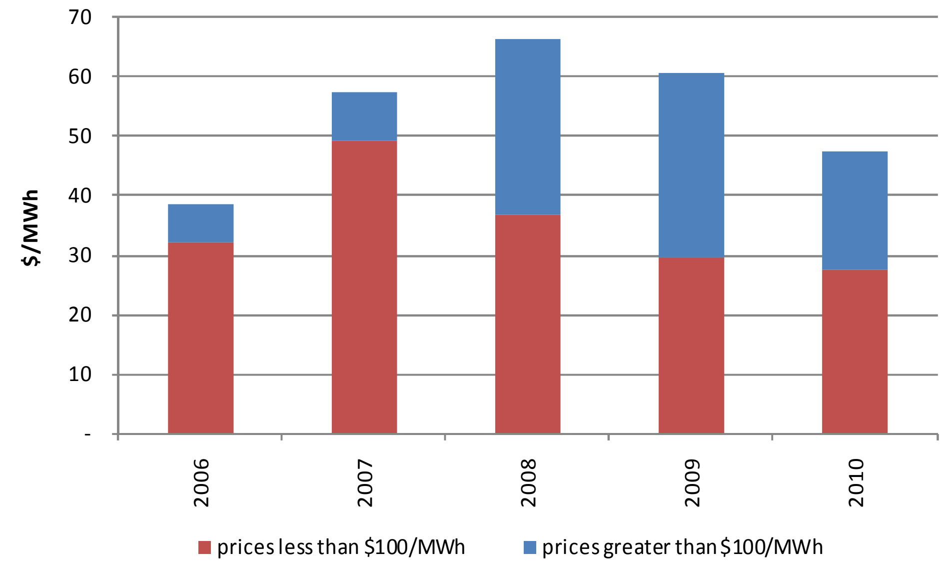
Figure 3 South Australian Premium Curves



This analysis assists in demarking the two distinct price distributions that underlie spot price behaviour in the market and their associated market conditions. On the basis of this analysis we define the first condition (amply supplied market) by spot prices less than $100/MWh, and the second condition (relatively short supply) by spot prices higher than $100/MWh.

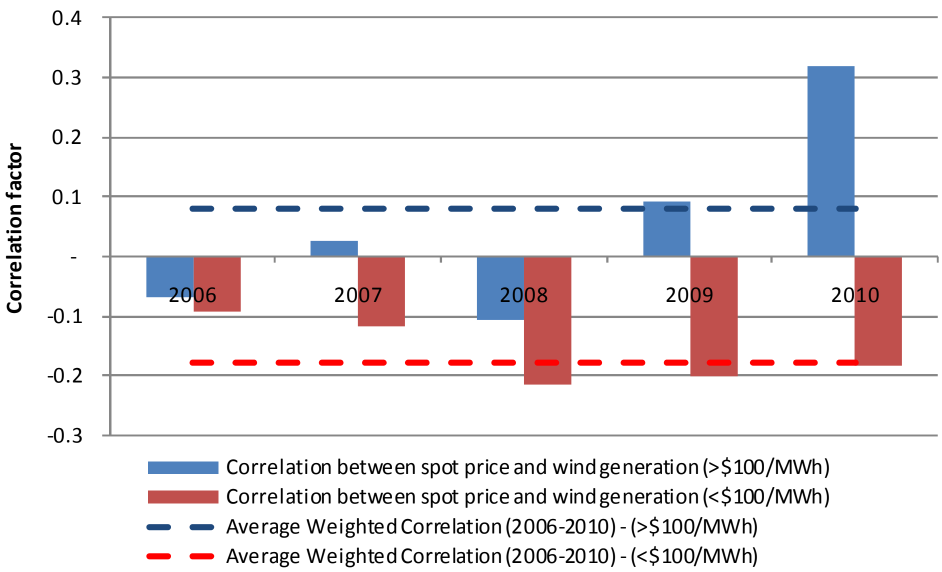
While the percentage of the time spot prices are higher than $100/MWh is relatively small, the MPC of $12,500/MWh is very high so prices above $100/MWh can have a large effect on the average annual spot price. This is evident from Figure 4 which decomposes the average annual spot price into contributions from component spot prices below and above $100/MWh. Clearly since 2008, the contribution of spot prices higher than $100/MWh has been relatively high accounting for some 50% of the value in 2009.

Figure 4 South Australian Annual Average Spot Prices



An analysis of the correlation between wind generation and intervals with prices lower and greater than $100/MWh respectively is shown in Figure 5.

Figure 5 Correlation between Spot Price and Wind Generation in South Australia



The analysis shows that the correlation between wind generation and low spot prices (<$100/MWh - shown in red) has been consistently negative from 2006 to 2010. Indeed the correlation has also become more pronounced as wind penetration has increased. On the other hand, observing the correlation between wind generation and high prices (>$100/MWh - shown in blue), any impact of low wind generation on high prices is less evident. If low wind generation were responsible for triggering high prices because the electricity market is less well supplied and more likely to experience tightness, we would expect to see a negative correlation. However, the sign of the correlation coefficient varies over the years suggesting that sometimes wind simply strikes it lucky by hitting high prices with high output and sometimes it doesn't. This leads us to conclude that at the current level of wind energy penetration, lulls in aggregate wind farm output are not drivers of high spot prices.

Modified Analysis

Motivated by the preceding observations we redo our initial analysis concerning the ratio of the average price received by the wind generation sector to the time-weighted price by first capping spot prices at $100/MWh to remove the effect of high spot price volatility, and then renormalising to account for the average value of prices above $100/MWh.

The results are shown in Table 3 and Figure 6.

Table 3 SA Average Spot Price and Wind Dispatch Weighted Price with $100/MWh Cap

Year	TWP Capped ($/MWh)	DWP Capped ($/MWh)	Discount ($/MWh)	Normalised Discount %
2006	31.77	30.28	1.49	3.2%
2007	49.01	46.70	2.31	3.6%
2008	36.87	33.61	3.26	6.3%
2009	29.48	25.94	3.54	8.0%
2010	26.20	22.20	4.00	9.7%

In the table above

Discount = TWP Capped – DWP Capped

Normalised Discount (%) = 1 – (DWP Capped + 15) / (TWP Capped + 15)

When expressing the discount as a percentage of the time weighted price, we add to the capped TWP and capped DWP a value of $15/MWh[ii] which we take to be a reasonable forward looking estimate of the average of the contribution of prices above $100/MWh.

After making these adjustments, a clearer picture of how the average spot price earned by the wind generation sector has gradually declined with respect to the annual average spot price emerges. In 2006, wind farms earned revenue at a discount of $1.5/MWh, in 2010, this increased to $4/MWh (shown in Figure 6). In Figure 7 we plot the price discount against wind penetration.

[ii] $15/MWh represents the average contribution from prices above $100/MWh in South Australia between 2004 and 2010.

Figure 6	Wind DWP discount with respect to the South Australian TWP, expressed in $/MWh and % of the TWP – with $100/MWh Cap

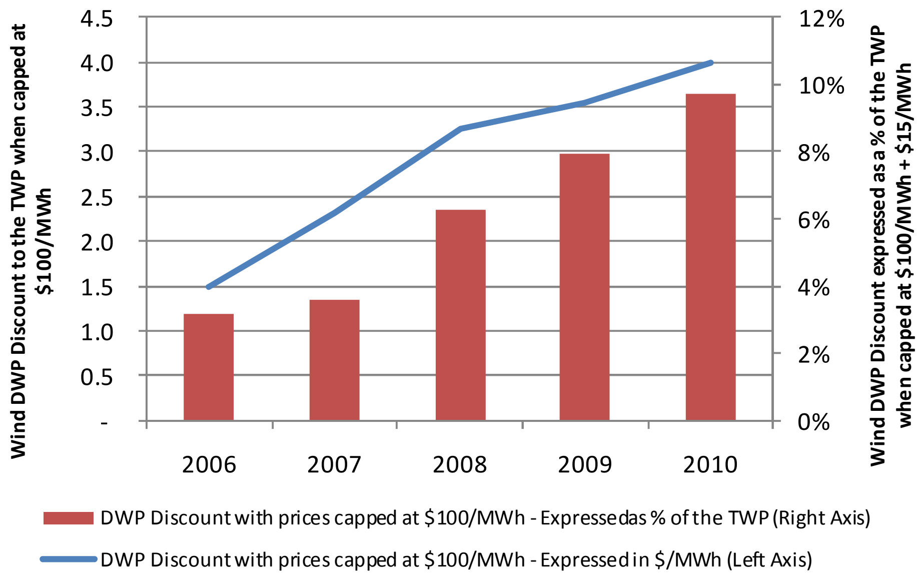
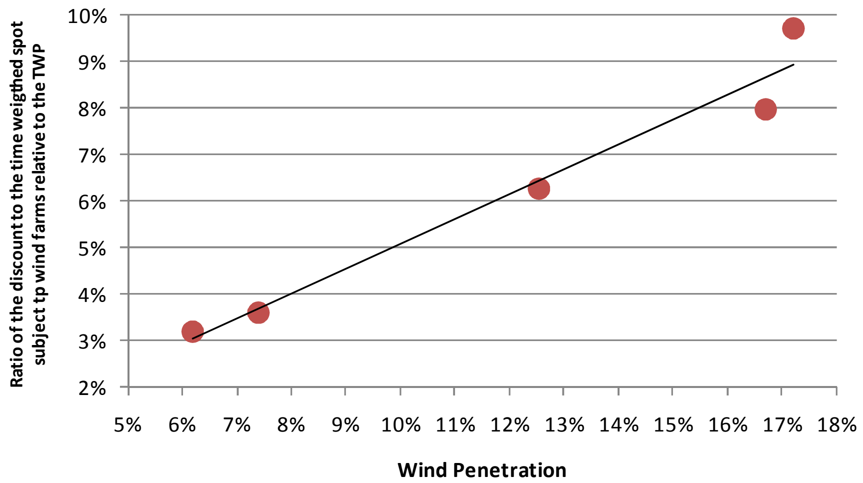


Figure 7	Normalised Wind DWF Discount to the TWP as a function of wind penetration in the South Australian Region



The average price received by the wind generation sector has declined relative to the annual average spot price, from a 3% discount in 2006, when wind energy penetration was 6%, to a 10% discount in 2010 where wind energy penetration now exceeds 17%. We note that some wind farms have been prepared to generate at -$1000/MWh, whilst it may be thought that this would provide a strong enough incentive to cease generating. Possibly the terms of their Power Purchase Agreement (PPA) remove that incentive. Clearly, if wind farms did not generate at those times, the discount to the TWP would be lower.

Nevertheless, on the basis of this trend, we may continue to observe a declining average price for the sector. Linear extrapolation suggests a 15% discount should wind energy penetration reaches 30%. However the discount could be higher, as arguably at some level of penetration, the occurrence of general wind lulls could result in high spot prices. Further it should be noted that the analysis is based on aggregate wind farm generation. New wind farms sited at locations which provide output with low correlation to existing wind farms can expect to fare better. Also increasing the interconnect capacity between South Australia and other regions would allow more wind energy to be exported with the prospect of arresting the decline in average spot price received for the sector as a whole.

Conclusion

South Australia has experienced significant investment in wind energy currently contributing to 17% of regional generation. Consistent with an increase in wind energy penetration, the average price received by the wind generation sector has attracted a growing discount to the annual average spot price.

Based on our analysis, as wind energy penetration in South Australia has increased, high wind generation has evidently contributed to low spot prices but it is not evident that low wind generation has led directly to very high spot prices.

We have justified and applied a method of data adjustment based on capping and renormalisation to uncover a consistent trend of price discount with wind penetration. Finally, as with all trend analysis, care should be taken with extrapolation.

Appendix

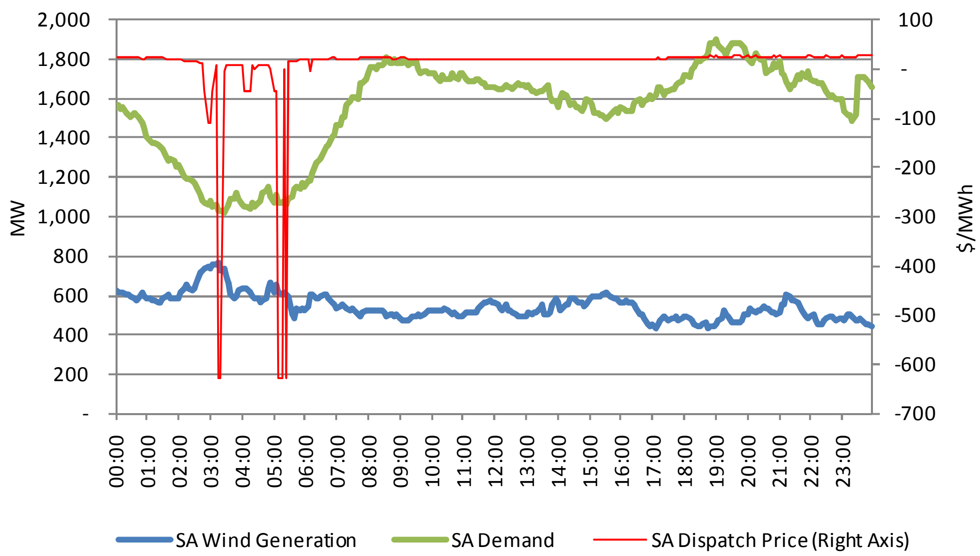
We take a look at two specific days, the 10th of September 2010 and the 3rd of October 2010. During these days South Australia experienced high negative electricity prices. These examples highlight the impact of increased wind penetration on the market.

10 September 2010

On 10 September 2010, the electricity spot price in South Australia averaged just over $7/MWh for the day. We accessed 5 min NEM dispatch data via the IES proprietary data-viewing tool NEO and set out to investigate the reasons behind this market outcome.

Between 3 and 6 am, the South Australian electricity price turned negative for 16 dispatch intervals. On 5 occasions the dispatch price reached -$627.33/MWh. South Australian demand, total wind generation and dispatch prices for the day are shown in Figure 8 below on a 5 minute basis.

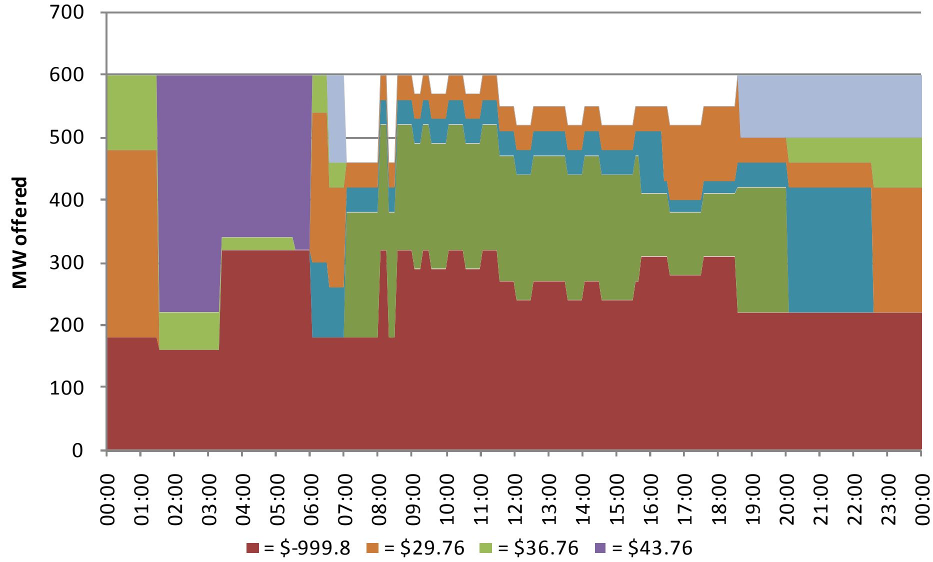
Figure 8 5 minute NEM data on 10 September 2010 in South Australia



Dispatch prices reached -$627/MWh at 3:20 and 5:20 am when wind generation was between 700 and 800 MW. Negative electricity prices resulted from a combination of high wind generation coupled with low regional demand and constraints on the interconnector to Victoria. Murraylink and Heywood combined was constrained to a maximum of 420 MW during the affected trading intervals. With excess generation capacity in South Australia, negatively priced generation offers were marginal for a number of dispatch intervals which resulted in high negative prices.

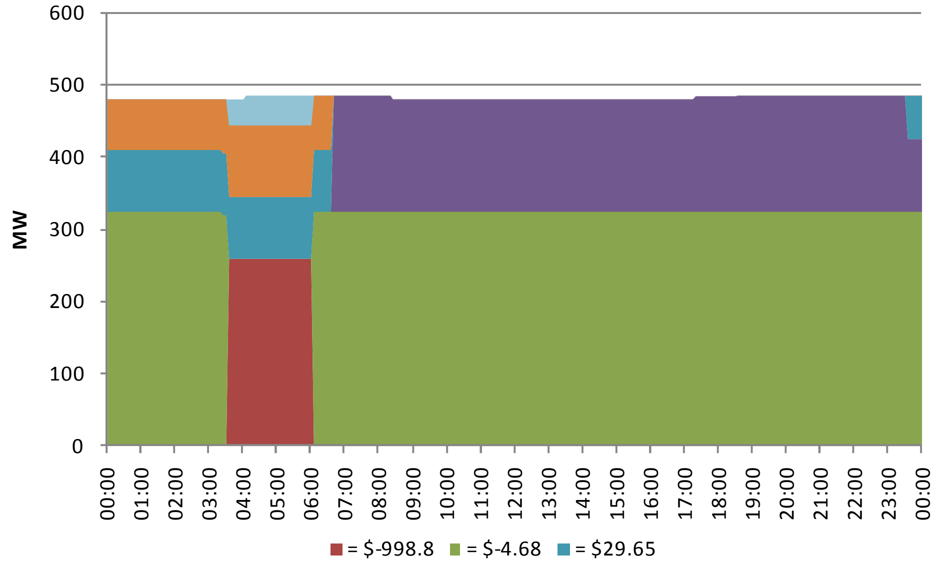
The significant amount of wind generation that occurred between 3 and 6 am on that day resulted in thermal power stations offering larger amounts of generation at the market floor of -$1000/MWh. Examples are shown in Figure 9 and Figure 10 for Torrens Island B and Pelican Point.

Figure 9 Torrens Island B Generation Offer on 10 September 2010



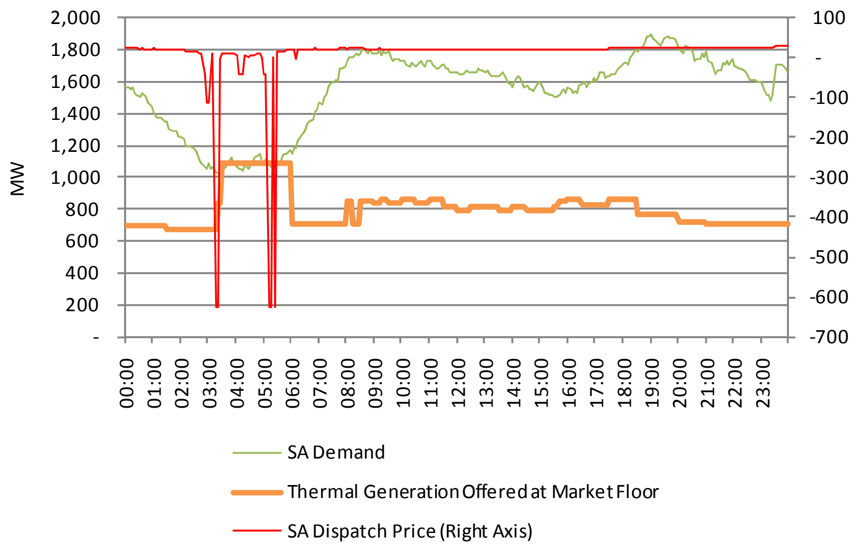
The amount of generation offered at the market floor by Torrens Island B increased from 180 to 320 MW in response to high wind generation. Similarly, Pelican Point offered 260MW at a price of -$1000/MWh. This block of generation was previously offered at -$5/MWh.

Figure 10 Pelican Point Generation Offer on 10 September 2010



Across South Australia as a whole, the amount of thermal generation offered at the market floor increased from 700 MW to 1100 MW in response to the increase in wind generation. This is shown in Figure 11 and would suggest that the real aggregated minimum generation level of thermal plants in South Australia is around 1100 MW.

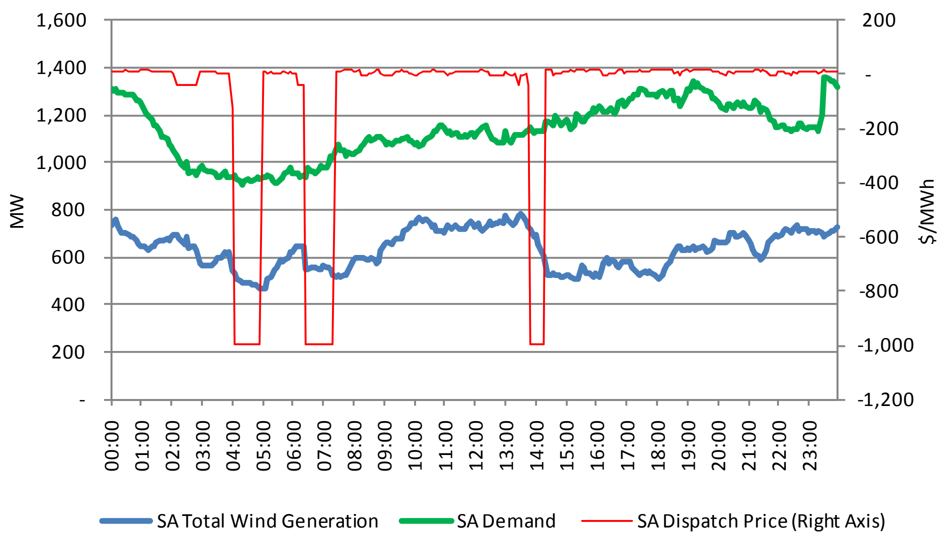
Figure 11 Thermal Generation offered at Market Floor in South Australia on 10 September 2010



3 October 2010

On 3 October 2010, the South Australian spot price averaged -$96/MWh for the day. The region recorded a minimum dispatch price of -$996.70/MWh on several occasions between 4:00 and 7:00 am and also at 2:00 pm. South Australian demand, total wind generation and dispatch prices for the day are shown in Figure 12 below on a 5 minute basis.

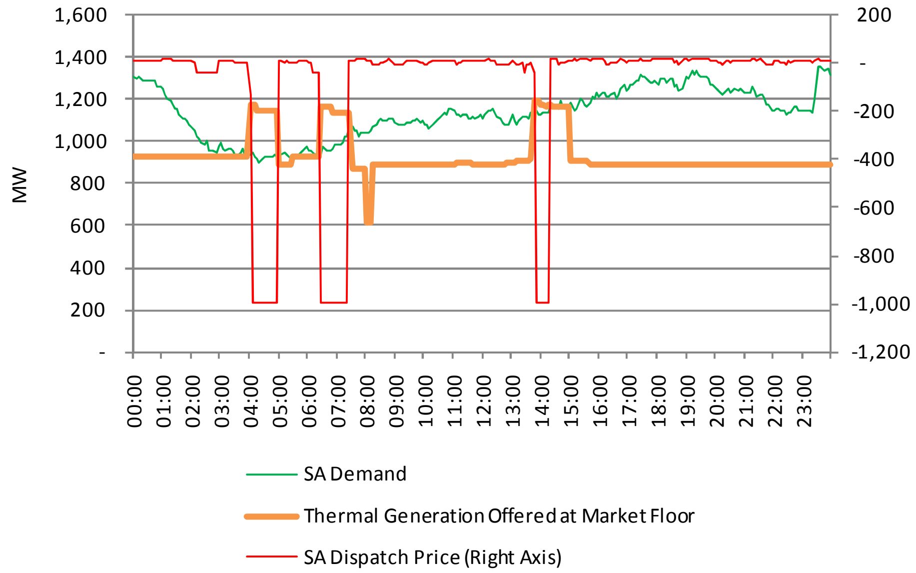
Figure 12 5 minute NEM data on 3 October 2010 in South Australia



The South Australia demand for the day was very low. More than 1600 MW of generation capacity was offered in negative price bands. During the periods of negative pricing, there was also substantial wind generation averaging around 590 MW between 4:00 and 7:00 am and up to 800 MW at 14:00. Transfer to Victoria on Murraylink and Heywood combined was constrained to a maximum of 420 MW during the affected dispatch intervals.

The amount of thermal generation offered at the market floor for the day is shown in Figure 13 below. Here again, the strong wind generation resulted in some thermal generators increasing the amount of generation offered at the market floor price.

Figure 13 Thermal Generation offered at Market Floor in South Australia on 3 October 2010



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