Sensitivity Analysis Of The National Electricity Market

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Abstract: This paper presents a sensitivity analysis of the National Electricity Market (NEM) in Australia. The electricity industry has experienced radical transformations in the last years. As in generation and retail sectors, transmission has also faced important changes. The power transmission grid is based on the open access policy to operate. Hence, all the participants of the electricity market have equal access to the transmission grid. In Australia, the generation units are situated over a wide geographic area and require an effective transmission network. At present, NEM contains four interconnected regions which are linearly linked to each other without any major bypass. The Australian national market is based on a pool market structure where all the electricity produced by the generation units is traded. The impact on pool price, and implicitly on the multi-area unit commitment solutions (scheduling of generation units) in the NEM is analysed by using three scenarios: different levels of inter-regional transmission limits (interconnectors) on the network, a different bidding strategy and a forced generation unit outage. The sequential multi-area unit commitment model (SMAUC_4) was run for all the above scenarios for a representative summer day, 20 January 2000, using half-hourly trading periods. This work shows that a higher inter-regional transmission capability will have a positive impact on pool price, will reduce significantly the actual level of regionalisation and will contribute to the creation of a true competitive market.

Keywords: *Sensitivity analysis; Pool price; Transmission; Bidding; Electricity.*

1. INTRODUCTION

The regions included in NEM are Queensland, New South Wales, Victoria and South Australia. These regions are linearly linked to each other without any major transmission bypass. At present, this market contains 223 generation units situated over a vast geographic area which require an effective transmission network (VenCorp 2000).

The scheduling of the units, together with the allocation of the generation quantities which must be scheduled to meet the electricity demand for a specific period, is called the *unit commitment* problem. A *multi-area unit commitment* represents two or more interconnected regions of a power system and is expected to provide substantial advantages.

In comparison with the old unit commitment approach, this modelling is applied in a deregulated market where each generation unit, is assumed being individual participant, and operates to maximise its own profits.

The multi-area unit commitment model was developed solely using the sequential method (Lee 1986, Li *et al.* 1997).

NEMMCO Market Data site provides half-hourly electricity demand for each state, day and period. Also, NEMMCO site provides the bids for each generation unit, 48 trading periods per day. The dataset, in form of public bids, contains the price offers, 10 band prices per day, and for each half-hour 10 band quantities are submitted. Data from NEMMCO was selected and rearranged in a proper format suitable to be used in model. For each day, each period, the new created bid file contains all the available units, their price and quantity bids.

The SMAUC_4 is run and the next best generation unit, as a function of bid price, is sequentially identified at each stage and committed until the electricity demand of each region is met, while all the constraints are satisfied.

2. POOL PRICE

In the actual deregulated electricity environment, the multi-area schedule of generation units including dispatch decisions is based on *pool price*.

The *pool price* is an average of the six 5-minute dispatch prices for each trading period (NEMMCO 2000).

The trading day is a 24-hour period commencing at 4:00 am Eastern Standard Time and contains 48 half-hourly trading periods. The generation units compete by offering their available capacity at different price levels. At present, the bid prices are between - $10, 000 and $10, 000.

The modelling of *pool price* has become an essential task in determining the multi-area scheduling of the most bid-efficient generation units, in order to meet the demand in all the regions, in each half-hour trading period.

3. SENSITIVITY ANALYSIS

3.1. Introduction

The impact on pool price, and implicitly on the multi-area unit commitment solutions (scheduling of generation units including units dispatch) is analysed by using three scenarios: different levels of inter-regional transmission capability on the network, a different bidding strategy and a forced generation unit outage.

The sequential multi-area unit commitment model (SMAUC_4) was run on all four interconnected regions of the national market, for the above scenarios, for a summer day, 20 January 2000. The selected day is representative for summer season with close to average temperatures and electricity demand.

The model is using 48 half-hourly trading periods and actual inter-regional transmission capabilities as shown in **Figure 1**. For example, Queensland and New South Wales are connected by two interconnectors: Queensland NSW Interconnector (QNI) and Direct Link (DL).

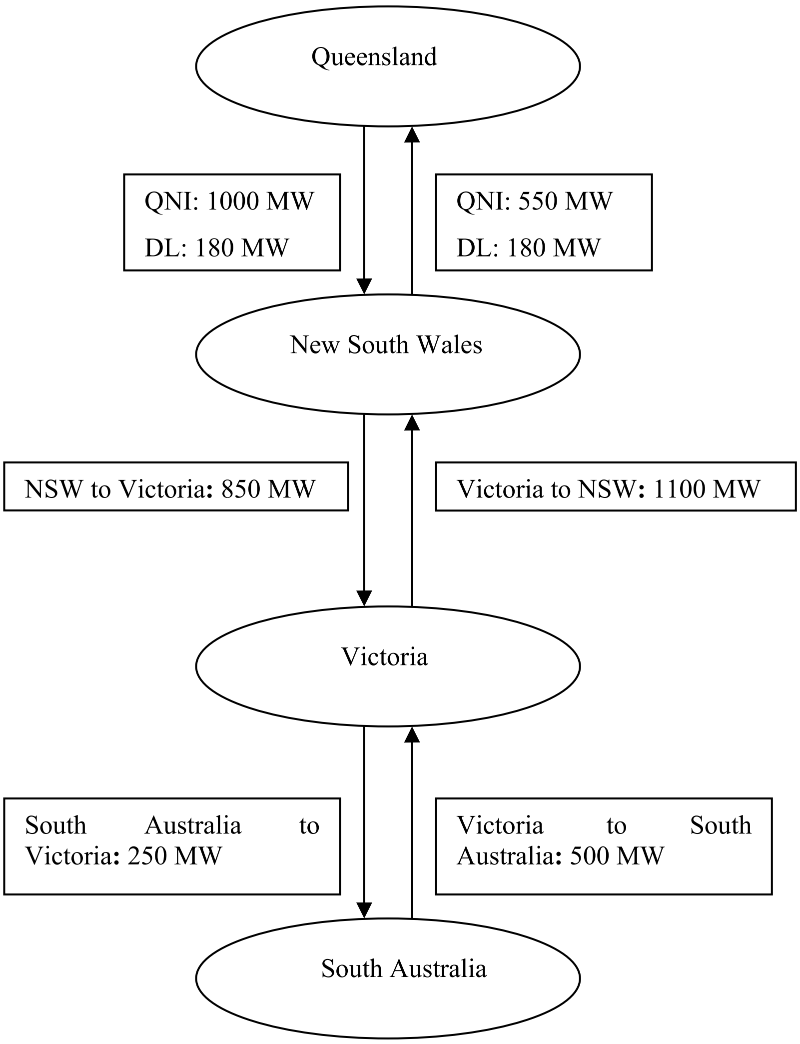

Figure 1, Inter-regional transmission capabilities of the NEM

3.2. Different levels of inter-regional transmission capability on the network

The following cases were considered relevant and applied in this scenario:

- **Base Case (BC)**: the inter-regional transmission limits are used as they are actually set in the national market (**Figure 1**).

- **No transmission (NT)**: the inter-regional transmission limits are set to 0 MW. As a result, there are in place four independent regional markets.
- **Limits decreased by 25% (Ld25)**: all the actual inter-regional transmission limits were decreased by 25% of their capacity.
- **Limits increased by 25% (Li25)**: all the actual inter-regional transmission limits were increased by 25% of their capacity.
- **Unlimited limits (UL)**: all the inter-regional transmission limits were increased to a very high level and there is in place only one market.

The SMAUC_4 was run for all the cases, for a representative summer day, using half-hourly trading periods, and the results are compared.

Victoria was the only region which remained with a constant average pool price of $13.11/MWh in all cases (**Table 1**).

Between the NT case and UL case, the pool price dropped dramatically by 50% in Queensland, 95% in New South Wales and 64% in South Australia. **Figure 2** shows the evolution of Queensland pool prices, by trading periods.

New South Wales exported to Queensland 100% of the time, while Victoria exported to New South Wales 88% of the time and 100% of the time to South Australia. The amount of electricity exported to South Australia increased by more than 2200 MW between Ld25 and UL scenarios (**Table 2**). Next tables show the maximum electricity sent for the summer day (**Table 3**) and the percentage time the inter-regional transmission capacities (interconnectors) were at maximum capacity (**Table 4**).

Table 1, Pool price summary ($/MWh), 20 January 2000

Scenario	Queensland	New South Wales	Victoria	South Australia
Base Case	$39.83	$28.56	$13.11	$54.51
No transmission	$77.84	$574.18	$13.11	$140.81
Limits decreased by 25%	$41.22	$28.56	$13.11	$60.22
Limits increased by 25%	$39.42	$28.56	$13.11	$52.36
Unlimited limits	$39.00	$28.56	$13.11	$50.47

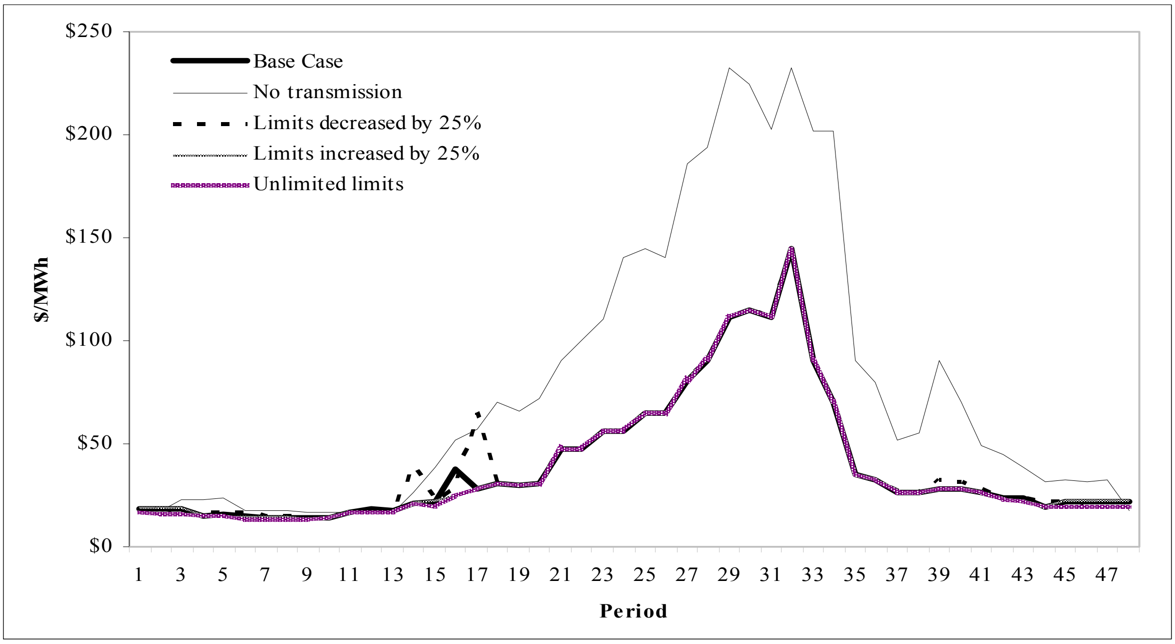

Figure 2, Queensland pool prices, 20 January 2000

Table 2, Total electricity summary (MW), 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0	10867	0	11221	9553	0
No transmission	0	0	0	0	0	0
Limits decreased by 25%	0	9973	0	11214	8167	0
Limits increased by 25%	0	11369	0	11204	10184	0
Unlimited limits	0	11966	0	11204	10454	0

Table 3, Maximum electricity sent out summary (MW), 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0	730	0	899	500	0
No transmission	0	0	0	0	0	0
Limits decreased by 25%	0	548	0	825	375	0
Limits increased by 25%	0	913	0	899	625	0
Unlimited limits	0	1257	0	899	771	0

Table 4, Percentage time constrained, 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0%	15%	0%	0%	31%	0%
No transmission	0%	0%	0%	0%	0%	0%
Limits decreased by 25%	0%	33%	0%	4%	56%	0%
Limits increased by 25%	0%	10%	0%	0%	17%	0%
Unlimited limits	0%	0%	0%	0%	0%	0%

The above cases show that inter-regional transmission limits have a considerable influence on the pool price, particularly in the regions were the electricity is offered at high prices, or in limited quantities. A higher inter-regional transmission capability is likely to reduce significantly reduce pool prices in the importing regions and slightly increase them in the exporting regions.

3.3. A different bidding strategy

In the new bidding scenario, the generation units radically changed their strategy and started to offer more electricity quantities at lower prices. The SMAUC_4 was run over a representative summer day and the following results were obtained.

The highest reduction in the daily average pool price was recorded in Queensland, where the decrease was $8.66/MWh. The pool price summary is shown in **Table 5**.

In this scenario, it was a decrease of approximately 1700 MW in the export from New South Wales, balanced by an identical increase in the total export from Victoria (**Table 6**). The interconnectors between NSW to Queensland and Victoria to South Australia were both at maximum capacity (**Table 7**).

Table 5, Pool price summary ($/MWh), 20 January 2000

Scenario	Queensland	New South Wales	Victoria	South Australia
Base Case	$39.83	$28.56	$13.11	$54.51
Bidding scenario	$31.17	$26.43	$11.44	$47.24

Table 6, Total electricity summary (MW), 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0	10867	0	11221	9553	0
Bidding scenario	0	9189	0	12633	9889	0

Table 7, Maximum electricity sent out summary (MW), 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0	730	0	899	500	0
Bidding scenario	0	730	0	988	500	0

It can be stated that pool prices and thus multi-area unit commitment solutions are volatile due to the impact of the bidding strategies used.

3.4. A forced generation unit outage

A forced generation unit outage is the last factor which is investigated in this study. In this scenario, the assumption was that in Victoria, Loy Yang A1 (LYA1) generation unit, with a capacity of 500 MW, experienced a forced outage for the whole day (20 January 2000). The impact of this event was analysed, using the newly created bids following the withdrawal of LYA1.

As in the previous scenarios, the SMAUC_4 was run for a summer day and the following results were obtained.

The forced generation unit outage affected radically all four regions. The pool price for Victoria almost doubled, Queensland experienced a 40% increase, New South Wales a 60% increase and South Australia a 25% increase (**Table 8**).

Victoria decreased its exports to South Australia by almost 1700 MW, to New South Wales by 5800 MW and, as a result, New South Wales decreased its export to Queensland by 2275 MW (**Table 9**). In this scenario the constrained interconnectors were Victoria to South Australia and New South Wales to Queensland (**Table 10**).

This factor is the main cause of high volatility of the pool prices in the national market.

Table 8, Pool price summary ($/MWh), 20 January 2000

Scenario	Queensland	New South Wales	Victoria	South Australia
Base Case	$39.83	$28.56	$13.11	$54.51
LYA1 outage scenario	$54.86	$45.26	$23.27	$68.49

Table 9, Total electricity summary (MW), 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0	10867	0	11221	9553	0
LYA1 outage scenario	0	8592	0	5412	7862	0

Table 10, Maximum electricity sent out summary (MW), 20 January 2000

Scenario	Qld to NSW	NSW to Qld	NSW to Vic	Vic to NSW	Vic to SA	SA to Vic
Base Case	0	730	0	899	500	0
LYA1 outage scenario	0	730	0	674	500	0

4. CONCLUSION

It can be stated that in a multi-area power system, pool prices vary significantly and are sensitive to variations in inter-regional transmission capability. Interconnector constraints produce different regional pool prices and facilitate local market power.

The lack of inter-regional transmission capability is one of the most important causes which undermine the competitiveness of any electricity market.

The impact of higher interconnection capability on pool prices and thus on multi-area unit commitment dispatch depends also on the bidding strategy of the generation units and forced outages in the power system.

The way in which the generation units set their bids (prices and quantities) has a great influence over the pool price and implicitly over the multi-area unit commitment dispatch. If the generation units shift big quantities of electricity to lower price bands, the market is settling close to the baseload short run pool prices. On the contrary, in case of the reduction of electricity offered at lower prices, interconnectors will be constrained and extreme prices are likely to appear. Usually, the generation units from exporting regions and the customers from importing regions obtained financial benefits.

The influence of a forced generation unit outage on the market is significant. It produces higher pool prices and increases the occurrence of price spikes. Constrained interconnectors cut the access to a valuable generation reserve from other regions and regional generation units have to supply all the required electricity demand, at any cost. In some cases, even the value of lost load condition (currently set to 10 000 $/MWh) may be reached.

It is expected that a higher inter-regional transmission capability will have a positive impact on pool price, will reduce the occurrence of price spikes, will reduce significantly the actual level of regionalisation and will contribute to the creation of a true competitive market.

5. REFERENCES

VenCorp, *Electricity Annual Planning Review 2000,* Victoria, Australia, pp. 20.

Lee, F.N., Short-Term Unit Commitment-A New Method, *IEEE Transactions on Power Systems*, Vol. 3, May 1988, pp. 421-428.

Li, C., Johnson, R.B., and Svoboda, A. J., A New Unit Commitment Method, *IEEE Transactions on Power Systems*, Vol. 12, No. 1, February 1997, pp. 113-119.

NEMMCO, *Statement of Opportunities,* Australia, 2000, pp. 3-6.