Portfolio Optimisation in the Australian Electricity Market

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EXTENDED ABSTRACT

The Australian electricity market has been deregulated. Most of the transactions in the deregulated energy market rely on bidding competition and the generators have to develop bidding strategies in order to maximise their revenue.

In this paper, a new bidding strategy methodology has been developed based on the optimisation of the entire generation portfolio. In general, a generation portfolio consists of a mix of baseload, intermediate and peaking plants[1]. The methodology uses the offer bids[2], contract quantity/strike price and half-hour forecast pool price. For each half-hour period, a function was designed to calculate the cash flows for the contracting position and the break-even price.

First set of bids is created and used for the Medium scenario. Iteratively from this set, another two sets of bids are created in order to optimise the profit for the higher and lower generation scenarios. Based on these three sets of bids, for each period of time, the most profitable bid is selected. This set of bids is used for the Base Case scenario.

Based on this model selection the portfolio may considerably increase its profitability and therefore improve its gross margin outcome. Although, this paper presents an example with a small number of plants, the methodology can be extended to a real size portfolio.

1. INTRODUCTION

The National Electricity Market (NEM), commenced on 13 December 1998 and comprised of Queensland, New South Wales, Victoria and South Australia markets. In May 2005, Tasmania joined the NEM. The NEM is a wholesale exchange (pool) operated by the Market Operator (NEMMCO) for trading electricity between market participants (generators) and wholesale customers.

Market participants submit their bid offers to NEMMCO who will dispatch the scheduled generation and demand according to their dispatch algorithm, based on the bid prices submitted by generators. NEMMCO's objective function is to minimise the cost of meeting demand and supply while electricity generators' objective function is to maximise their revenue, taking into consideration the strategic behaviour of their competitors.

The strategic optimisation and bidding has been extensively discussed. Many papers looked at optimising bids for the whole market in order to minimise the total system cost and calculate the clearing price for the market (Hao *et al.* (1998), Alvey *et al.* (1998)). Other models like conventional economic dispatch tried to minimise only the generation cost as opposed to profit maximisation (Ilic *et al.* (1998)).

2. DATA

The model was developed based on an assumed electricity generator portfolio consisting of two baseload plants with a capacity of 200 megawatts (MW) each, an intermediate plant of 100 MW and a peak plant of 50 MW.

For this simulation, the following contract situation was assumed for the portfolio: 250 MW flat swaps with the strike price[3] of $35/MWh, 100 MW off-peak swaps at $20/MWh, and 100 MW peak swap[4] at $75/MWh. The running operations costs were set at $15/MWh for the baseload plants, $35/MWh and

[1] A generator which is expected to run at around 5% capacity factor is assumed to be a peaking plant, above 80% capacity factor is assumed to be a baseload plant and anywhere in between is considered an intermediate plant.

[2] A generator's offer bids consist of price bands and associated quantity bands.

[3] The price, which is specified in the option contract, at which the underlying futures contract will move from seller to buyer.

[4] A swap is a derivative where two counterparties exchange one stream of cash flows against another stream

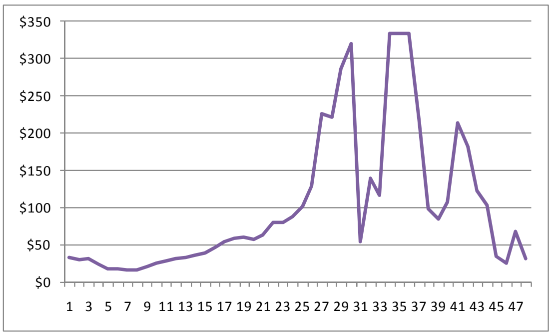
$90/MWh for the intermediate and peaker plants respectively.

The statistics of the forecast pool prices for one day is presented in Table 1 below and the half-hourly figures are shown in Figure 1.

Table 1: Summary statistics for forecast pool price ($/MWh)

	Forecast Pool Prices ($/Mwh)
Average Pool price	101.61
Maximum	333.33
Minimum	16.65
Standard Deviation	94.95

Figure 1: Forecast Half-Hour Pool Prices



3. DEFINITIONS

$$t = period\ (half-hours),\ t = \overline{1,48}$$

$$s = scenario,\ s \in \{M, L, H, BC\}$$

$$i = unit\ index = \begin{cases} 1,2, & for\ intermediate \\ 3, & for\ baseload \\ 4, & for\ peaker \end{cases}$$

$$b = bid\ band\ number,\ \mathrm{b} = \overline{1,10}$$

$$PB_{b,i} = bid\ price\ for\ unit\ i\ in\ band\ b$$

$$Q_{b,i,t,s} = available\ quantity\ for\ band\ b,\ unit\ i,\ period\ t,\ in\ scenario\ s$$

$$DQ_{i,t,s} = forecast\ dispatched\ quantity\ for\ unit\ i,\ period\ t,\ in\ scenario\ s$$

$$UC_i = total\ capacity\ for\ unit\ i$$

$$FP_t = forecast\ pool\ price\ for\ period\ t$$

$$SW_t = scenario\ selected\ for\ BC\ for\ period\ t$$

$$C_i = cost\ \$/MWh\ for\ unit\ i$$

$$F_{i,t} = flag = \begin{cases} 0, & if\ unit\ i\ is\ NOT\ available\ in\ period\ t \\ 1, & if\ unit\ i\ is\ available\ in\ period\ t \end{cases}$$

$$n = number\ of\ total\ contracts$$

$$S_n = strike\ price\ for\ contract\ n$$

$$M_{n,t} = quantity\ sold\ for\ contract\ n,\ period\ t$$

$$q_{b,i,t,s} = quantity\ needed\ to\ be\ moved\ from/to\ band\ b,\ unit\ i,\ period\ t,\ in\ order\ to\ construct\ the\ new\ bids\ for\ scenario\ s = L\ and\ s = M$$

$$BP_t = break-even\ strike\ price\ for\ portfolio,\ period\ t$$

$$g = \%\ change\ in\ FP_t = \begin{cases} +10\%, & if\ s = L \\ -10\%, & f\ s = H \end{cases}$$

$$FTPR_{t,s} = forecast\ pool\ revenue\ for\ period\ t,\ scenario\ s$$

$$FTCR_{t,s} = forecast\ contract\ revenue\ for\ period\ t,\ scenario\ s$$

$$FTC_{t,s} = forecast\ cost\ for\ period\ t,\ scenario\ s$$

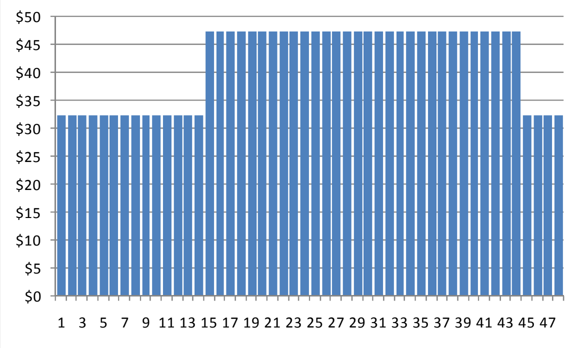
$$FTP_{t,s} = forecast\ profit\ revenue\ for\ period\ t,\ scenario\ s$$

4. MODEL

The model was built in three stages.

In the first stage, a function was designed to calculate the cash flows based on the half-hour portfolio contracts and the break-even price for the portfolio. An example or the break-even price for this simulation is presented in Figure 2 below. Of note is that the break-even price is not equal to the strike price of individual contracts, because for each period there might be different contracts with different strike prices. Also, in real life, there are very complex contract types (e.g. a combination of swaps, caps and swaptions).

Figure 2: Break-even contract price for the simulation



In this stage for each period solve BP_t such that:

$\sum_{k=1}^{n}\left(BP_t - S_k\right)\times M_{k,t} = 0$, which gives the break-even contract price: $BP_t = \dfrac{\sum_{k=1}^{n}\left(S_k \times M_{k,t}\right)}{\sum_{k=1}^{n} M_{k,t}}$.

In the second stage, an initial set of bids was created such that the baseload plant is dispatched between 85% and 100% of the capacity, the intermediate plant at 45% to 60% and the peaking plant below 5% (opportunistic dispatch). The units have to generate at least to cover the contract level for each period, therefore the next condition has to be met.

$$\sum_{i=1}^{4}\left[F_{i,t}\times\left(\sum_{\substack{b=1\\ PB_{b,i}\le \min(BP_t, FP_t)}}^{10} Q_{b,i,t,M}\right)\right]\le \sum_{k=1}^{n} M_{k,t}$$

This initial set of bids was considered the basis for the medium case calculation.

In the final stage, three scenarios were developed using the forecast price. The "Medium generation" scenario (MScen) uses the initial bids developed in the first step. For the "Low generation" (LScen) and "High generation" (HScen) scenarios, the bids are calculated iteratively from the first set of bids so that the profit is optimised for each period.

For LScen and HScen, , $maximise\left(FTP_{t,s}\right)$, where $FTP_{t,s} = FTPR_{t,s} + FTCR_{t,s} - FTC_{t,s}$ and solve the system to find $q_{b,i,t,s}$ such that all the following conditions are met.

$$\sum_{b=1}^{10} Q_{b,i,t,s} \le UC_i$$

$$Q_{b,i,t,s} \ge 0,\ for\ any\ b,i,t,s$$

In LScen, the bid quantities are moved in the higher priced bands, therefore the plants are generating less, being more opportunistic. It is assumed in this case that due to these quantity movements (less generation in lower priced bands), the forecast pool price increases by 10% (arbitrary chosen for this simulation).

$$Q_{b,i,t,s} = \begin{cases} max\left(Q_{b,i,t,M} + q_{b,i,t,s}, 0\right), & for \begin{cases} s = H\ and\ b \le 4,\ or \\ s = L\ and\ b > 4 \end{cases} \\ max\left(Q_{b,i,t,M} - q_{b,i,t,s}, 0\right), & for \begin{cases} s = L\ and\ b \le 4,\ or \\ s = M\ and\ b > 4 \end{cases} \end{cases}$$

In HScen, the bid quantities are moved in the lower priced bands, therefore the plants are generating more, being price takers and trying not to set the price for the region. It is assumed in this case that due to these quantity movements, the forecast pool price decreases by 10% (arbitrary chosen for this simulation). Generation for each of the three scenarios are shown in Appendix A. The generation, pool and contract revenue and costs are calculated using the next equations:

$$DQ_{i,t,s} = F_{i,t}\times\left(\sum_{\substack{b=1\\ PB_{b,i}\le(1+g)\times FP_t}}^{10} Q_{b,i,t,s}\right)$$

$$FTPR_{t,s} = (1+g)\times FP_t \times \sum_{i=1}^{4} DQ_{i,t,s}$$

$$FTCR_{t,s} = \sum_{k=1}^{n}\left\{\left[(1+g)\times FP_t - S_k\right]\times M_{k,t}\right\}$$

$$FTC_{t,s} = \sum_{i=1}^{4}\left(DQ_{i,t,s}\times C_i\right)$$

Once the new bids are created, each scenario uses the contract function and forecast prices adjusted for each case (no change for MScen, +10% for LScen, -10% for HScen) in order to calculate the generation, pool revenue, contract revenue, cost of generation and profit for each period.

Although the easier way is to choose the scenario that gives the higher profit, it is much better to look at the profit period by period and choose the best individual scenario, and afterwards constructs a new set of bids based on the each chosen period combination. For Base Case (BC), for each period a scenario is selected such that:

$FTP_{t,BC} = max\left(FTP_{t,L}, FTP_{t,M}, FTP_{t,H}\right)$ and

$SW_t = s$, for each $FTP_{t,BC} = FTP_{t,s}$. The bids are constructed using SW_t index for each period t band b. For each unit the proposed bid quantities are given by Q_{b,i,t,SW_t}. These bids are submitted for the day to NEMMCO who will dispatch each individual unit.

5. RESULTS

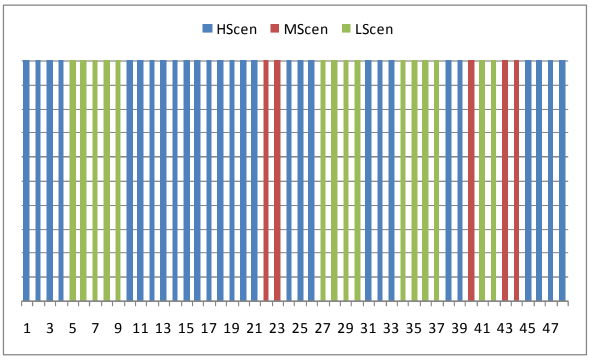
The results for the day for each scenario are shown in Table 2. The best overall profit result is obtained in HScen.

Table 2: Result for each scenario

[redacted]

For the Base Case, the selection of the most profitable scenario for each period is shown in Figure 3.

Figure 3: Scenario selection for each period



The resultant profit for the Base Case, using the forecast price is $605,580 for the day, which is $44,000 above HScen.

6. CONCLUSION

In the last two decades numerous energy markets have been deregulated worldwide. In a competitive energy market, generators have to improve their biding strategies in order to increase their performance.

In this paper, a different bidding strategy was proposed based on the optimisation of the entire generation portfolio.

The methodology uses the offer bids, contract quantity/price and half-hour pool price. For each half-hour period, a function was designed to calculate the cash flows for the contracting position and the break-even price for the pool price such that the contracts would be profitable. In this way, a decision regarding the preparation of an optimised bid price and quantity of portfolio plants can be easily taken.

By using this model the portfolio may considerably increase its profitability and therefore improve its gross margin outcome. This methodology can be extended to a real size portfolio.

7. REFERENCES

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APPENDIX A

Generation in different scenarios: