The Competitive Market for Electricity in Australia: Why it Works so Well

Hugh Outhred
School of Electrical Engineering and Telecommunications
University of New South Wales
h.outhred@unsw.edu.au

Abstract

The National Electricity Market is the centerpiece of the Australian restructured electricity industry. It is a spot market in which prices are determined on a five-minute basis but half-hour averages are used for commercial transactions. The five-minute prices are broadcast to participants so that they can respond while the prices are still avoidable. An approximate form of nodal pricing is used.

This market has proved to be an effective design in terms of competition between generators, but is as yet far from perfect. The need for evolution in market rules was recognized in the market implementation, and refinements to the design may be expected for some years to come.

This paper discusses key issues involved in the implementation of competition in the electricity industry and then discusses strengths and weaknesses of the Australian National Electricity Market design. Suggestions are made as to how the market design might be improved.

1. Introduction

The implementation of competition in an electricity industry is a complex and time-consuming process that has many pitfalls. Unfortunately it is easier to see the problems with the traditional industry structure than predict those that will arise in future restructured industries.

Section 2 of this paper summarizes some of the fundamental issues involved in implementing electricity industry competition. Section 3 considers the important issue of market power. Section 4 describes key features of the Australia's restructured electricity industry, focussing on the design of the Australian National Electricity Market (NEM). The NEM is the centerpiece of electricity industry restructuring in Australia, a process that is not yet complete nearly a decade after it commenced.

Section 5 considers strengths and weaknesses of the Australian design, some of which are illustrated by the trading results discussed in Section 6. Section 7 describes arrangements for risk management associated with the NEM. Section 8 discusses some important boundary issues that remain unresolved in the NEM design. Finally, Section 9 summarizes lessons learned to date.

2. Implementing electricity industry competition

The objective of electricity industry restructuring is to replace highly regulated, centralized decision making with lightly regulated decentralized decision making in a competitive environment. However the underlying physical behavior of an electricity industry remains the same through such a transition. Therefore in considering restructuring, it is useful to consider three differing perspectives on a competitive electricity industry:

- *A complete physical model* – which consists of the electrical network, all electrical equipment connected to it in power stations and consumers' premises and all the associated automatic control systems that are in operation. Because electrical energy propagates through a network at the speed of light, all these components interact in an instantaneous fashion, regardless of size or location. For example, all operating generators in an electricity network are electrically connected to all electricity-consuming equipment that is operating, even the smallest appliance. Also, the lack of cost-effective methods to store electrical energy means that the supply/demand balance at any location in a network can change extremely rapidly due to unexpected demand or the failure of network or generating equipment. Thus there is a great deal of short-term uncertainty in the physical behavior of an electricity industry. Finally, the laws of physics, not those of commerce, govern the physical behavior of the industry.
- *Mathematical models* – various representations of the industry that are used for simulation and design purposes. Mathematical models are greatly simplified approximations of the physical model and may not be fully accurate representatives of physical behavior. These abstract models are used for various purposes – for example designing control systems or predicting network flow patterns.

- *Commercial models* - representations of the industry that are used for commercial trading purposes. These may incorporate simple mathematical models of the industry. When combined with the commercial decision making of electricity industry participants, these models provide the commercial "blueprint" for how the electricity industry is to evolve through time, covering both operation and investment time scales. To be effective, commercial trading must manage both short-term operation and future risk, but this objective is handicapped by the limited accuracy of the commercial models.

There are inevitable mismatches between physical operation of an electricity industry and the abstract representations of the commercial models. For example:

- Commercial models can never model all the short-term uncertainty of physical electricity industry behavior. Thus they typically assume adequate quality of supply (voltage magnitude, frequency, waveform purity, phase balance, etc). However quality of supply must be actively managed in reality, and many of the control systems that appear in the physical model are concerned with managing quality of supply (both immediately and in the future). The need to manage physical behavior outside the commercial models may pre-empt the commercial decision-making, and at the very least creates boundary problems that must be resolved for both operation and future risk management.
- Small consumers typically purchase electricity from electricity retailers rather than participate directly in commercial electricity trading. Thus small consumers may not even appear as participants in the commercial trading models. However because of the nature of the electricity industry, the equipment of small consumers appears directly in the physical model. Thus small consumers must be represented in some fashion in commercial models, typically by demand forecasts. Unfortunately the use of demand forecasts may create problems of unallocated risks in the commercial trading models.

Mismatches between a commercial model of an electricity industry and the underlying physical reality must be managed in the short term by resources known as 'ancillary services' and network pricing arrangements and in the longer term (if required) by regulatory intervention. Ancillary services may themselves be subject to commercial trading in a competitive electricity industry. Ancillary service trading is secondary to the main commercial trading arrangements, and is inherently more complex because the traded products are less clearly defined. Also, boundary problems can arise between ancillary service trading and commercial electricity trading because the underlying physical industry is a continuum whereas ancillary services and commercial trading regimes are (at least to some extent) distinct. Moreover, ancillary services are likely to be provided by spot market participants, thus joint product problems arise.

Speaking generally, the smaller the mismatches between the commercial model used for electricity trading and the underlying physical reality, the less that reliance need be placed on ancillary services and regulatory intervention.

The wholesale electricity market implemented in England and Wales is an example in which there are large mismatches between the commercial model and the underlying physical reality:

- A single node commercial trading model is used, which tacitly assumes that all market participants are at one location. Ancillary services and network pricing arrangements must then be used to manage location effects, such as network losses and flow constraints.
- A day-ahead market is used, thus unanticipated events within the trading day must be managed by ancillary services. Also, the complex market algorithm that is used exacerbates opportunities for participants to exercise market power.

The perceived shortcomings of the England and Wales model have recently led to a proposal to radically change its nature.

By contrast, the spot market in the PJM pool in the USA incorporates a DC load flow model of the transmission network to implement a form of nodal pricing. While this has been called 'full-nodal pricing', it is in fact approximate. For example, a DC load flow model is not a fully accurate model of a transmission network and cannot resolve voltage – reactive power issues and distribution networks are not modeled at all. It is too early to know whether the PJM approach will be regarded as a successful model for implementing electricity industry competition.

3. Market power

As indicated, market power is a key concern with electricity restructuring. Unfortunately, the nature of the electricity industry provides many opportunities for the exercise of market power:

- In most electricity industries, a relatively small number of producers (power stations) supply a much larger number of consumers (loads). Furthermore power stations usually operate in either base-load, intermediate or peaking duty.
- Even when there is close balance between supply and demand on a network-wide basis, network flow constraints can create sub-regions in which there is poor supply/demand balance, with either excess or shortage of generation in a sub-region. Network flow constraints are often set from an ancillary service perspective without full regard to their commercial implications.

- The lack of cost-effective means to store electrical energy means that constrained supply conditions may develop suddenly, either in local areas or network-wide.

Thus market power must be carefully considered in electricity market design and an appropriate balance must be struck between reliance on competition and reliance on regulation. A market design should be chosen that facilitates both effective competition and effective regulation.

4. Australia's 'National Electricity Market'

The Australian electricity industry has been undergoing a restructuring process for the last decade. This process has involved disaggregating former state-owned monopoly utilities both vertically and horizontally and introducing competition. In some cases, the resulting state-owned businesses have been sold.

The centerpiece of the restructured industry is the Australian National Electricity Market (NEM), a multi-region spot market that covers the States of Queensland, New South Wales, Victoria and South Australia. Spot prices in NEM are determined every five minutes by an economic dispatch algorithm and broadcast to all market participants in 'real time'. All electricity is traded at half-hourly averages of the five-minute spot prices, thus participants can respond to the spot prices as they evolve. Participant offers and spot prices are only capped at a value designated as VOLL (value of lost load) that is currently set at AUD 5000 per MWh, but will rise to AUD 20,000 per MWh over the next few years. VOLL also applies whenever load must be shed to maintain power system integrity.

Four key principles underlie the design of the NEM spot market:

- Marginal pricing
- Spot pricing
- Location-dependent pricing
- Decentralized decision-making, including the management of risks.

Marginal pricing is implemented via the economic dispatch algorithm, which selects the cheapest available resource (as indicated by the offers submitted by market participants) to meet incremental changes in the demand experienced by the real power system.

The design of the NEM is fully symmetric so that in principle, supply and demand side participants have equal opportunity to set and respond to market prices. However to date, few demand-side resources are formally bid into the market. Thus price-elasticity effects are not well represented and prices are more volatile than they should be. Instead, demand forecasts are fed into the economic dispatch process, weakening the link between the commercial trading model and physical reality and introducing demand forecast risks that are not managed commercially.

Spot pricing is implemented by broadcasting the five-minute prices to participants in 'real time'. Moreover bids and offers can be modified until a half-hour before they apply (although participants can be asked to provide reasons for such changes). Thus supply and demand side participants are able to respond to the prices that actually apply at any given time. Moreover, demand side participants can respond to high five-minute spot prices by reducing demand without having to formally notify the market operator.

There are no capacity payments in the NEM and operating decisions such as unit commitment or de-commitment remain the responsibility of the participant concerned. Projections are broadcast of how the half-hourly prices are expected to solve for the following day and these projections are updated on a three-hourly basis to reflect changes in bids and offers, unit availability and forecast demand.

Location-dependent pricing is implemented by the following three-level arrangement:

- The wholesale market is divided into market regions such that frequently occurring flow constraints appear on region boundaries (region boundaries are to be re-set as required to track changing patters of network constraints). Inter-connectors between regions are modeled in a simplified and abstracted fashion in the spot market.
- Intra-regional network loss factors are calculated for each transmission node within market regions in the form of averaged marginal loss factors. These are presently re-calculated on an annual basis using historical network flow data from the previous year.
- Distribution network loss factors are based on average rather than marginal losses. They are also averaged geographically over distributor service territories. This approach is a compromise between economic efficiency and equity objectives. The location-dependent price signals are thus less accurate for distribution networks than for transmission networks.

The combined effect of these network modeling arrangements is that each participant in the NEM sees an approximate form of nodal pricing, in which the spot price at its particular node bears a pre-determined relationship with the spot price at the regional reference node in its market region. This approximately reflects the effect of network losses but does not model intra-regional network flow constraints. Alternative risk management arrangements are being considered for such constraints.

The level of flows in the inter-connectors between regions determines the relationship between the spot prices at the regional reference nodes. The spot prices at the regional reference nodes are all related when no inter-connectors are constrained (with one marginal participant), but separate into two or more independent groups (with multiple marginal participants) whenever one or more inter-connectors are constrained.

Approximate nodal pricing based on marginal pricing principles produces settlement residues. That is, the amount of money paid to the market operator by purchasers of electricity exceeds the amount paid to generators. Settlement residues can be used to defray some of the costs of providing network services. However most revenue for network service providers is still obtained through regulated network service charges.

NEM spot prices reflect the uncertainty in the underlying electricity industry due to the absence of cost-effective means to store electrical energy and spot prices have proved to be volatile. Over time it is anticipated that participants will develop strategies that take account of this price volatility and, as a result, reduce it through price-elasticity effects.

The intent of the NEM design is to allow projected prices and real-time prices to guide participant behavior such that supply-demand balance is maintained with the minimum need for management of modeling mismatches through ancillary services.

A pre-dispatch process in which spot prices are forecast one day ahead supports this intent. In addition, a process of 'projections of system adequacy' (PASA) forecasts supply/demand balance (without price projections) up to two years ahead.

Despite the relative accuracy of the NEM spot market with respect to the physical world, ancillary services are still required. These were initially implemented in a manner reminiscent of the traditional monopoly utility world, but commercial arrangements for ancillary services are now being implemented.

Reference [1] contains a more complete discussion of the options available for network representation in electricity spot markets and discusses some of the reasons behind key design choices made for the Australian NEM.

5. Strengths and weaknesses of the NEM

Strengths of the NEM design include the following:

- The simplicity of the spot market design enhances participant trust in the outcomes and reduces opportunities for the undetected exercise of market power.
- The inclusion of an approximate representation of the network in the spot market algorithm has allowed some competition to be applied to the provision of network services. For example, an unregulated inter-connector is currently under construction that will link the New South Wales and Queensland regions of the NEM. In what is believed to be a world-first, this inter-connector will receive no guaranteed revenue and will have to rely on profits earned from exploiting the differences in spot prices between each end of the link. These differences mainly arise from differences in regional reference prices but also from the effects of network loss factors. A similar project between the New South Wales and South Australian regions of the NEM is now in the planning phase.
- Decentralized unit commitment has proved to be practical for steam-cycle generators because they are usually concerned with (relatively infrequent) de-commitment decisions rather than (frequent) commitment decisions. Moreover the NEM design places steam-cycle generators under pressure to 'reveal preferences' in their offers as failure to be accepted in any half-hour period would lead to de-commitment with resulting re-start costs.
- The combination of spot market design simplicity and price volatility has encouraged active trading in derivatives linked to spot price for risk management and market discovery purposes. Effective commercial management of risk is essential to the effective operation of a competitive electricity industry.

Weaknesses of the NEM design include the following:

- Spot price volatility in principle should encourage fast-start generators and demand management activities. However high-price events that last for only a few five-minute intervals may not provide adequate commercial returns for fast-start generators. In fact the use of an economic dispatch algorithm to set five-minute spot prices has introduced boundary problems between ancillary services and spot market design. These will be discussed later in the paper.
- Ideally, spot prices represent willingness to buy or sell at a uniform average power level during a spot market interval. Thus they should be set independently of short-term technical constraints such as ramp-rate limits. However the five-minute dispatch process must take ramp-rate constraints into account because it is a 'physical world' process. Half-hour ex-ante prices and quantities, set as the last step of a 'technical forward market' process may prove to be a better choice than the current five-minute, thirty-minute hybrid (see [1] for details).
- The use of network loss factors is an imperfect representation of network location effects in the spot market. Various improvements are being considered, including more frequent recalculation of network loss factors and the use of more detailed network models in the spot market algorithm. However all the alternative options for representing network effects have weaknesses as well as strengths and it appears that there is no single perfect solution to this problem. Rather, approaches may have to be used that are appropriate for

different aspects of network service – inter-connectors, regional transmission and distribution.

6. Results of electricity trading in the NEM

The NEM formally commenced trading in December 1998, superseding an interim arrangement that combined pre-existing state-based markets in New South Wales and Victoria.

Figure 1 shows price duration curves (truncated at $300/MWh) for the Victorian market for four years commencing July 1994. Figure 1 illustrates how the cumulative effect of competitive pressures over time coupled with effective market design has caused market participants to 'reveal their preferences'. This figure also illustrates the phenomenon of price volatility – very high prices occur occasionally when supply is constrained with respect to demand. Note that high prices don't only occur at times of high demand, because factors such as the operating generator plant reserve margin and the level of contract cover are also relevant to price outcomes.

One question that arises with competitive electricity industries is whether investment in new capacity will take place in time to maintain adequate reliability of supply. While this question can probably never be fully answered, experience with the NEM to date has not given grounds for serious concern.

Market prices have generally been higher on average in the Queensland and South Australian regions of the market (where there are lower reserve plant margins), than in the New South Wales and Victorian regions (where there are higher reserve plant margins). Likewise, most new capacity investment is occurring in Queensland and South Australia and there are no indications that serious supply constraints will arise in the next few years. It must be noted, however, that some of this investment has been encouraged by State government policies.

Figure 2 shows price data published by the National Electricity Code Administrator (NECA) for the Victorian region of the NEM for the period December 1998 to June 1999. Daily maximum and minimum plus 28 day average data sets are shown.

Figure 2 shows a continuation of the behavior illustrated for earlier years in Figure 1. That is, considerable price volatility superimposed on generally low spot prices, albeit with an upward average trend in the later part of the period.

7. Facilities for risk management

As previously indicated the volatile spot prices in the NEM encourage trading in financial instruments linked to future spot prices. Regional reference prices are normally used because the use of pre-determined network loss factors means that there is no remaining basis risk in nodal prices (in the absence of intra-regional flow constraints). This improves financial instrument market liquidity.

Most financial instrument trading is generally one of the following kinds:

- Vesting contracts implemented by State governments as part of the restructuring process. Vesting contracts have been used to underwrite the profitability of generating companies during the transition process, by placing financial obligations on retailers with respect to their franchise customer bases.
- Voluntarily negotiated "contracts for differences" associated with NEM regional reference prices. These contracts are usually hedging arrangements between generating companies and retailers.
- Call option contracts, typically purchased by participants to cap their financial exposure to high spot prices.

Financial instrument trading occurs through three paths:

- Direct bilateral negotiation based on purposed designed contracts
- Direct bilateral negotiation based on over-the-counter contracts
- Exchange-traded monthly contracts based on either average spot prices or peak-period average prices at regional reference nodes.

Initially, contracts were mainly of the first kind but the latter two categories are becoming more popular as they are easier to price and to trade.

In addition, facilities have recently been introduced for managing the risks associated with the differences between the spot prices at the regional reference nodes.

These arrangements now operate as follows:

- Each regulated inter-connector modeled in the NEM spot market is regarded as consisting of two notional directional inter-connectors.
- The settlement residue associated with each notional directional inter-connector is identified.
- Regular auctions are held for three-monthly rights to the settlement residues of each notional directional inter-connector.
- The proceeds of the auctions are returned to the owners of the regulated inter-connectors.

Potential purchasers of settlement residue rights include the owners of generation who wish to enter hedging contracts with consumers located in other market regions.

For example, the Snowy Mountains Hydroelectric Authority (SMHEA) is a hydro generator with its own NEM region. Thus it would be exposed to significant financial risk if it entered hedging contracts with consumers without the protection of access to the settlement residue associated with the inter-connectors that connect it to the other market regions.

While the introduction of settlement residue auctions is an important step forward in risk management, it introduces additional potential for the profitable exercise of market power. For example, the SMHEA clearly has the power to set spot prices in its region under some circumstances. At those times it also has the ability to influence the settlement residues associated with inter-connectors to its region. Similarly, to prevent them consolidating their local market power, generators in South Australia have been excluded from the auctions for settlement residues associated with the notional directional inter-connector to South Australia.

8. Boundary issues in the NEM design

The NEM spot market currently serves two main purposes:

- Through the price setting process, it determines the spot prices for electricity that market participants will pay or be paid.
- Through the economic dispatch process, it manages the physical resources that are available to meet actual demand, taking ramp-rate limits into account.

Thus the spot market contains aspects of both the commercial world of electricity trading and the physical world of ancillary services.

This hybrid arrangement creates a number of problems:

- The setting of spot prices is influenced by participants' physical characteristics, distorting the 'pure' commercial objective of the spot market.
- Some resources, such as fast-start combustion turbines, do not receive clear signals about their commercial value to the spot market.
- Opportunities for gaming spot market prices are enhanced.
- Demand forecast uncertainty contributes to spot-price uncertainty without clear accountability for the associated commercial risks

As previously mentioned. the NEM design has created difficulties for the commercial management of fast-start peaking plant such as combustion turbines that have start-up times of the order of minutes and minimum run-times of the order of an hour. The key problem is that high spot price periods in NEM may only last for a few five-minute intervals (for example as a result of demand forecast uncertainty), in which case it may not be profitable (nor possibly economically sensible) to start combustion turbines. Various remedies are currently under consideration, including forecasting of five-minute prices.

A more radical solution to this problem would be to implement an 'ex-ante' half-hour spot market that was 'purely commercial', in the sense that it took no account of participants' physical characteristics. Such a market would in essence be a forward market, in which participants submitted their bids or offers to produce or consume and were financially committed to a pattern of behavior determined by the market solution. Real-time variations from this pattern would expose participants to financial risk and would also form a basis for assessing accountability for ancillary services. This approach would be more effective if implemented as the final stage of a 'technical forward market chain' that looked ahead one or two days and replaced the present PASA functions provided in NEM. It would be even more effective if retailers and direct consumers were required to bid their anticipated demand into this ex-ante market. See [1] for a more detailed discussion of this approach.

9. Conclusions

The Australian National Electricity Market may be regarded as an important experiment in the process of implementing electricity industry competition. In particular, it has demonstrated the feasibility of decentralized commitment of base-load generating units, and the competitive pressures that can be achieved with careful market design.

However the NEM has a number of design weaknesses that may prove difficult to fully eliminate, despite the existence of procedures for changing market rules. The most important of these weaknesses are:

- Boundary issues between ancillary services and spot markets
- Incorporation of more accurate location signals, with respect to ancillary services, spot market and risk management.
- Introduction of effective competition for small consumers, including questions concerning spot market representation and risk management arrangements.

Regulation will be required for the foreseeable future and challenges remain in the search for an effective combination of competition and regulation.

10. References

[1] H.R. Outhred and R.J. Kaye, "Incorporating Network Effects in a Competitive Electricity Industry: An Australian Perspective Chapter 9 in M Einhorn and R Siddiqi (eds), *Electricity Transmission Pricing and Technology,* Kluwer Academic Publishers, 1996, pp 207-228.

[2] National Electricity Code Administrator (NECA), "Market Surveillance and Monitoring – Quarterly Report April – June 1999, July 1999.

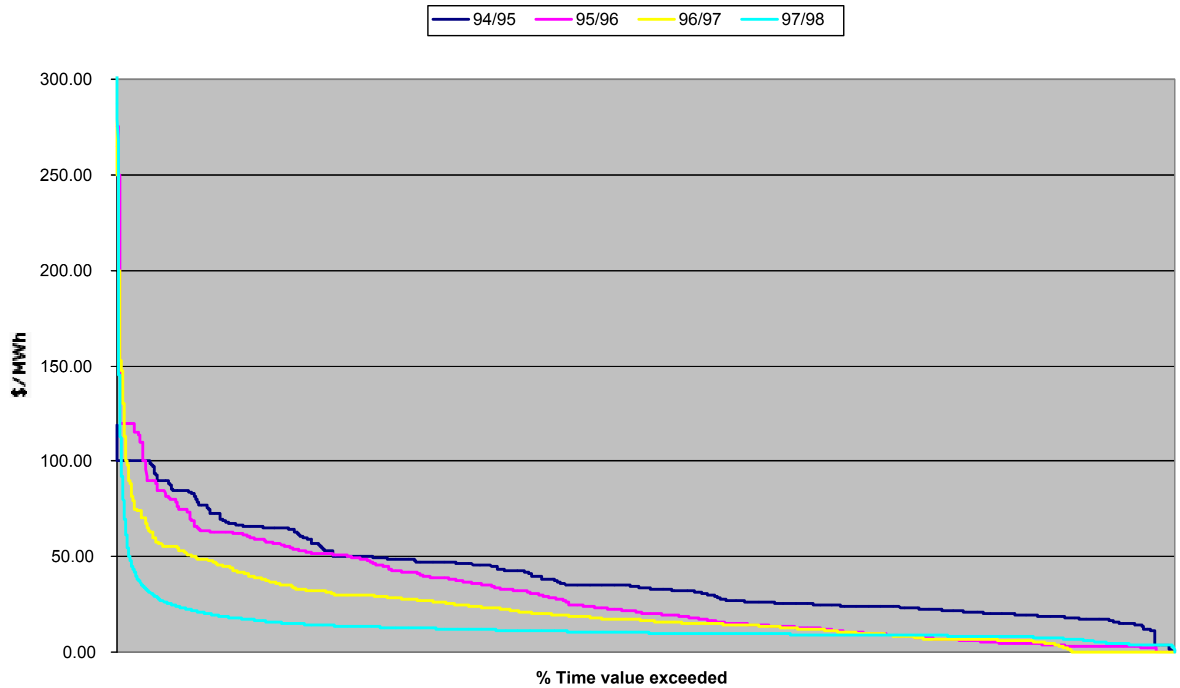

Figure 1. Victorian Price Duration Curves

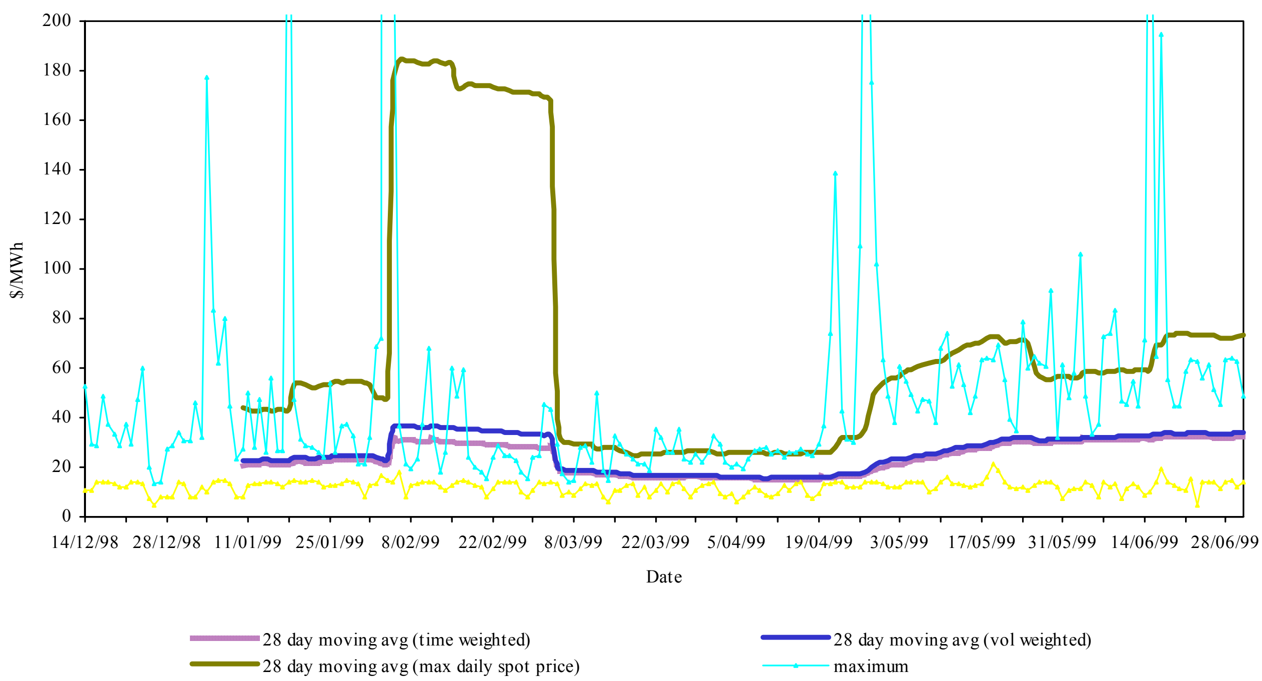

Figure 2. Price data for the Victorian region of the National Electricity Market from December '98 to June 1999 [2]