A Review of Experience with Commercialising and Regulating Network Services in the Australian Electricity Industry

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ABSTRACT

The electricity industry operates by maintaining a continuous flow of electricity from generators to end-use equipment in an uncertain environment in which both availability and quality of supply are important. Network equipment operating in a holistic manner plays a critical role in maintaining acceptable industry operation and yet this role is not clearly separable from the roles played by generators and end-use equipment. Thus the services provided by the network are not clearly separable from the services provided by generators or loads, and the services provided by individual items of network equipment are not clearly separable from each other nor from those provided by the network as a whole. Some aspects of the treatment of network services in the Australian electricity industry sometimes reflect these characteristics but other aspects do not, leading to incompatibilities and contentious issues. There are clear improvements that could be made and many of these have been identified in recommendations of a number of industry inquiries and reviews. However, it is not clear that there is the understanding or political will to implement them.

1. INTRODUCTION

The task of an electricity industry is to deliver end-use energy services, such as illumination, computing services and space conditioning by maintaining a continuous flow of electrical energy to end-use equipment in an uncertain environment. At its simplest, an electricity network connects electricity generators to end-use equipment, providing the current paths necessary for the transfer of electrical energy between the two. Each generator injects a continuous flow of electrical energy into the electricity network at its point of connection and each item of end-use equipment absorbs a continuous flow of electrical energy at its point of connection.

However, the network's role is more complex than that description would suggest. A generator cannot inject electrical energy nor can an item of end-use equipment absorb it without the connecting current paths provided by the network. Moreover, quality of supply matters as well as availability. The network plays a vital role in maintaining availability and quality of supply and providing robustness against deteriorations in availability or quality due to the failure of a generator, network or end-use component, or fluctuations in power flows.

Thus the network provides an aggregation function by which all operating generators maintain a continuous flow of electrical energy to all operating end-use equipment, despite the stochastic nature of individual generator and load behavior. This aggregation function can be thought of as implementing an obligatory, industry-wide, just-in-time contract that efficiently manages the short-term variations between the stochastic supply and demand patterns of individual generators and end-use equipment, subject to network losses and flow constraints.

The ratings of individual network elements create an outer set of flow constraints, which may exhibit complex patterns due to the phenomenon of "loop flow". Security constraints, set by power system operators on the basis of risk assessment, may create an inner set of flow constraints. Security constraints take account of possible future modes of behaviour during normal operation plausible equipment outages that may prejudice availability and/or quality of supply and switchgear interruption capability. Security constraints are thus risk management tools rather than deterministic limits.

Many of the services provided by an individual network element are holistic; they depend on other network elements and in important cases also on generators and/or loads. Many network services are instantaneous and continuous, and are identifiable more by their absence than by their presence. For example, the network may play an important role in maintaining security of supply that is not readily observable in the absence of blackouts. Also, the ability of the network to continue to deliver network services depends on decisions taken by system and generator operators and end-users as well as by network owners.

The strong dependences between generators, networks and end-use equipment and the subtle nature of network services create serious barriers to the commercialisation of network services. The same characteristics mean that network services are difficult to regulate. For example, network investment decisions can have significant impacts on the commercial outcomes for both generators and end-users.

Therefore the treatment of network services remains contentious in restructured electricity industries. In particular, the common carriage model in which a network supports bilateral trading between generators and retailers or end-users does not capture the complexities of the network role in power system operation and planning. More sophisticated approaches to electricity industry restructuring are required, which implement an effective combination of centralized (regulated) decision-making and decentralized (commercial) decision-making to manage the temporal and spatial uncertainties that are such a critical feature of electricity industry operation and investment [1].

2. DECISION-MAKING IN A RESTUCTURING ELECTRICITY INDUSTRY IN THEORY AND PRACTICE

In an ideal restructured electricity industry, there would be a decision-making framework that adequately replicated the full energy conversion chain from primary energy resources to end-use energy services. This would include a representation of network impedances and flow constraints, availability and quality of supply, and important social and environmental externalities. Generators, network service providers and end-users would all participate in the same decision making framework and decisions would be decentralised to an appropriate extent in a combination of regulated and commercial decision-making. Energy service facilitators who supported and aggregated end-use decision-making would replace electricity retailers.

A decentralised framework for power system operation and planning was proposed in [2] and the concept of quality of supply pricing was postulated in [3]. The role of pricing policies was further developed in [4] and [5]. The latter demonstrated that forward-looking pricing policies that address uncertainty are required, including participant-specific pricing signals for those participants who can influence market outcomes. Unfortunately many network operating and investment decisions have the latter characteristic, increasing the challenges to be addressed by a commercial approach to network services.

A commercial framework that incorporates network characteristics was described in [1]. This "Nodal Auction Model" implements a "hub and spoke" approximation to nodal pricing and includes the possibility of using "voltage-value functions" to incorporate willingness to pay for voltage regulation. [6] and [7] illustrate the application of this concept to simple power system models. The central proposition of this approach is that the commercial framework for a restructured electricity industry should be based on nodal markets, aggregated to a level that supports good price discovery in ancillary service, spot and derivative markets. This approach would require active demand-side participation in all markets to resolve network flow constraints and [8] discusses how it addresses the continuous flow characteristics of the electricity industry.

Important features of the Nodal Auction Model have been adopted in the design of the Australian National Electricity Market. However it has not been implemented fully, particularly with regard to demand side participation or choice of market regions, and there is some doubt that it ever will. Thus at present, and for the foreseeable future, operating and investment decisions are made in a hybrid world of mixed market-based and centrally planned decision making, with ambiguous boundaries between the two.

In particular, electricity industry restructuring in Australia has to date attempted to largely quarantine operation and investment decisions for network services from decisions for generation and end-use, apart from the innovative concept of a "market network service", which will be discussed later. This reflects a still unresolved debate in Australia between the "common carriage" and "nodal market" models of network services. This inconsistent approach to network services creates difficulties in the treatment of power system security, embedded generators, end-use efficiency and demand management.

The implementation of efficient retail markets would ameliorate these problems. Unfortunately efficient retail electricity markets are complex even for small end-users, who require appropriate metering, end-use equipment, decision-making tools and support from "energy service facilitators".

Recent broad assessments of the Australian experience in implementing electricity restructuring appear in [8, 9]. This paper will focus on the treatment of network services.

3. TREATMENT OF NETWORK SERVICES IN THE AUSTRALIAN NATIONAL ELECTRICITY MARKET

3.1 Overview

According to [10], the "recognition of the need for a strongly interconnected, and closely coordinated, national transmission network provided the initial impetus for the work that led to the creation of the market. Controversy has continued to rage, however, around the role of the transmission network, and around the regulatory and incentive framework within which transmission and distribution network providers should operate as the sole remaining regulated monopolies within an otherwise competitive market".

The key challenges as seen by [10] were to:

- "establish a stable framework for essential new investment in regulated and unregulated interconnectors, in order to meet the fundamental objective of enabling capacity and reserve to be shared market-wide.
- provide a consistent basis for network pricing that will give improved signals for essential new investment, and ensue that the costs of that investment are met those who benefit from it; and
- work towards closer integration of the energy market and network services."

A key issue underlying the first two bullet points above is to determine when investment in new network assets is justified.

In the Australian National Electricity Market, the Regulatory Test promulgated by the Australian Competition and Consumer Commission, which is presently under review [11], governs augmentation of regulated network assets. A proposed augmentation satisfies this test if -

- in the event the augmentation is proposed in order to meet an objectively measurable service standard linked to the technical requirements of schedule 5.1 of the Code - the augmentation minimizes the net present value of the cost of meeting those standards; or
- in all other cases - the augmentation maximizes the net present value of the market benefit having regard to a number of alternative projects, timings and market development scenarios, where market benefit means the total net benefits of the proposed augmentation to all those who produce, distribute and consume electricity in the National Electricity Market. In practice, this test measures benefits in terms of reduced operating costs, reduced unserved energy and deferred investment in generation.

Under recent changes to the National Electricity Code, network service providers are given responsibility for administering the regulatory test, including the obligation to assess feasible alternatives. Capital cost recovery for regulated transmission networks uses the concept of optimised deprival value and cost recovery from retailers and consumers according to an assessment of their usage of the network. Capital costs for distribution networks are recovered according to a simplified and aggregated network-pricing algorithm, which smoothes differences between locations in distribution networks.

The third item in NECA's list of issues [10] relates to the representation of network services in the National Electricity Market. This has the following aspects:

- Models of the interconnectors between regions of the National Electricity Market are incorporated directly into the spot market, so that in principle, no separate network pricing is required for inter-ties and "market network service providers" can participate in the market.
- Network losses within market regions are represented in the National Electricity Market pricing algorithm, which has the effect that separate prices are calculated for each transmission connection point Together with the model of interconnectors, this gives a "hub and spoke" approximation to nodal pricing.

These arrangements represent important innovations in electricity market design that have many good features. Nevertheless, they are not entirely satisfactory, as will be discussed in Section 4. However, first they will be discussed more fully in the following subsections.

3.2 Representation of inter-ties between regions of the National Electricity Market

Inter-regional loss factors and constraint equations are used to represent the losses and constraints associated with energy flows on regulated interconnectors between market regions. The inter-regional loss factors are used as price multipliers that determine the ratio between regional reference node prices in adjacent market regions unless there are binding flow constraints. They represent "the additional electrical energy loss for each additional increment of electricity transmitted through regulated interconnectors from a regional reference node in one region to the reference node in an adjacent region for a particular time period and a defined range of operating conditions" (National Electricity Code Version 1 Amendment 8 Clause 3.6.1). The inter-regional loss factors are determined by inter-regional loss factor equations that are based on "an analysis on load, generation and network data for each trading interval in the previous financial year" (i bid) that is updated annually. Forward-looking loss factors are also calculated.

Energy flow between market regions on a regulated interconnector is deemed to be constrained "when for operational regions it is not acceptable for the regulated interconnector to transfer the level of electricity between regions that would be transferred if the limitation was removed" (National Electricity Code Version 1 Amendment 8 Clause 3.6.4). Interconnector flow constraints can arise for many reasons, including equipment thermal limits and security constraints.

This representation of a regulated interconnector is a significant abstraction from the underlying physical network that is only applicable to a transmission network with a near-linear structure. Nevertheless, it allows the National Electricity Market to provide useful commercial signals with respect to the effect of losses and flow constraints associated with interconnectors.

The regional structure of the National Electricity Market also permits the concept of a market network service (National Electricity Code Version 1 Amendment 8 Clause 2.5.2). A market network service is provided by a two-terminal link that is independently controllable, has a power transfer capability of at least 30 MW and that has its two connection points in different network regions. A market network service is offered into the National Electricity Market in a similar fashion to a generator, except that it offers the service of transfer of electrical energy from one market region to another.

3.3 Representation of intra-regional transmission and distribution networks within regions of the National Electricity Market

The effect of transmission network losses within market regions is represented in the National Electricity Market by the use of intra-regional network loss factors, which act as multipliers between the spot price at the regional reference node and each other transmission network node in the market region. They "notionally describe the additional electrical energy losses for each additional increment of electricity transmitted between a regional reference node and transmission network connection point in the same regional for a defined time period and associated operating conditions" (National Electricity Code Version 1 Amendment 8 Clause 3.6.2). An annual average loss factor is used rather than one calculated for each spot market period. Distribution networks are also represented by distribution loss factors but in a more aggregated fashion.

Flow constraints within market regions can only be partially represented given the National Electricity Market design principle that market regions will be chosen so that all significant flow constraints are placed on boundaries between market regions. Thus, intra-regional network constraints are taken into account in the dispatch process but generators that are constrained with respect to the regional reference node are not permitted to set the spot price at the regional reference node. When supply is constrained within a sub-region, network service providers may negotiate confidential commercial arrangements with local generators to bring them on-line to avoid blackouts but this occurs outside the market and does not affect prices in it.

4. STRENGTHS AND WEAKNESSES OF THE TREATMENT OF NETWORK SERVICES IN THE NATIONAL ELECTRICITY MARKET

The representation of network services in the National Electricity Market is innovative and at least partially successful. For example, the concepts of market regions, notional interconnectors and network loss factors have provided a useful "hub and spoke" approximation to nodal pricing, while retaining adequate price discovery to support derivative trading at regional reference nodes.

However, the concept of market network services has met with mixed success, and one of the three market network services constructed to date has been granted conversion to regulated status. One of the difficulties is that the Code permits the co-existence of regulated and non-regulated interconnectors between market regions and while this is feasible for the operation of existing links [12], there are practical difficulties with regard to investment.

For example, after a detailed assessment of the experience with competing proposals for regulated and nonregulated links into the South Australian region of the National Market, [13] concluded that: "Australian experience suggests that, for interconectors, overexpansion by regulated transmission may be a more serious concern than underinvestment by merchant transmission". This is partly as a result of practical difficulties in applying the Regulatory Test in an objective manner, partly due to organisational drivers in regulated network service providers and partly due to political drivers that see a "strong" regulated interconnected network as a defence against public concerns about high spot prices and blackouts [13]. However, as pointed out in [14], further strengthening of interconnectors will do little to reduce the risk of blackouts.

It has also proved difficult to effectively regulate providers of distribution network services, particularly with respect to giving equal consideration to distributed resources (embedded generation, storage and demand side options) as an alternative to distribution network augmentation. For example, in the final report in its Inquiry into the Role of Demand Management and Other Options in the Provision of Energy Services, the Independent Pricing and Regulatory Tribunal stated: "It is the Tribunal's strong view that there is significant untapped potential for efficient demand management" [15]. The Tribunal went on to make far-reaching recommendations to overcome this deficiency, which included:

- The establishment of a demand management fund and various other support measures for demand management, energy efficiency and embedded generation.
- Trials of congestion pricing and accelerated availability of interval metering for small end-users.

In 2002, The Council of Australian Governments established a review of energy markets [16], which considered network issues as part of its brief. Exhibit 4 of the review final report sets out the issues and proposed solutions shown in Table 1. The proposed solutions would take the market further in the direction of a nodal market model of network services rather than towards a common carriage model.

Table 1 COAG energy market review key findings and proposed solutions related to transmission [16, Exhibit 4]

Key findings	Proposed solutions
Transmission planning is fragmented	Give NEMMCO responsibility for transmission planning
It is not possible to obtain "firm" financial rights to underpin interstate contracting	Have NEMMCO auction "firm" financial transmission rights (FTRs)
The transmission augmentation process is flawed	Use the price of FTRs as the key indicator of the need for transmission augmentation
Regulated transmission entities face poor incentives that can conflict with the needs of the market	Introduce explicit incentives that penalise/reward transmission entities according to the availability of lines during times of most pressing market need
The current regions do not suit the needs of the NEM	Allow the number and location of regions to be set by the needs of the NEM

Government response to these findings and the process of electricity industry restructuring more generally appears confused and reluctant to abandon the "common carriage model". For example, in July 2003, the National Electricity Market Ministers Forum (NEMMF) issued terms of reference for a further transmission review "to assist the Ministers determine the appropriate way forward for transmission regulation" [17]. The review terms of reference assert:

- the fundamental role of transmission is to provide a transportation service in the NEM;
- in certain cases transmission competes with generation and demand-side management;

- there is a central and ongoing role for the regulated provision of transmission in the NEM, and some scope for competitive provision.

These mixed signals will make it difficult to develop good policy on network services.

5. DISCUSSION AND CONCLUSIONS

The early stage of electricity restructuring in Australia benefited from an informed and inclusive development process. As a result, the design of the National Electricity Market is innovative and successful in many respects. However, representation of network services in a restructured electricity industry is a complex and challenging problem and many issues were left unresolved in the initial implementation. For example, see [18] with respect to embedded generation.

It is always important to remember that the electricity industry operates by maintaining a continuous flow of electricity from generators to end-use equipment in an uncertain environment, in which both availability and quality of supply are important. Network equipment operating in a holistic manner plays a critical role in maintaining acceptable industry operation and yet this role is not clearly separable from the roles played by generators and end-use equipment. Thus the services provided by the network are not clearly separable from the services provided by generators or loads, and the services provided by individual items of network equipment are not clearly separable from each other nor from those provided by the network as a whole.

To be successful, a commercial model of the electricity industry should reflect these physical characteristics. Statements such as *"the fundamental role of transmission is to provide a transportation service"* [17] do not provide a sound basis for a robust commercial model of an electricity industry.

As discussed in [1], a nodal or location-based approach provides a sounder basis for commercialising the electricity industry, in which there are local markets for ancillary services, spot energy and derivatives that are geographically aggregated to an appropriate extent. The extent of aggregation should be reduced over time subject to issues of liquidity and price discovery to be finally based on the distribution networks served from each zone substation. To be successful, this approach requires active demand side participation and, because all end-users share the same network, small as well as large end-users must be actively involved. In this model, the network provides arbitrage services between the local markets subject to network losses and flow constraints, and, as indicated in [16], differences between derivative prices in local markets would provide signals for, and revenue to support, network augmentation.

Thus there are clear improvements that could be made to the treatment of network services in the Australian restructured electricity industry and most of these have been identified in recommendations of a number of industry inquiries and reviews. However, it is not clear that there is the policy-level understanding or political will to implement them.

6. REFERENCES

[1] Outhred, H. R. and Kaye, R. J. 1996. Incorporating network effects in a competitive electricity industry: an Australian perspective. *Chapter 9 in M Einhorn and R Siddiqui (eds), Issues in transmission pricing and technology*: Kluwer Academic Publishers: 207-228.

[2] Schweppe, F. C.; Tabors, R. D.; Kirtley, J. L.; Outhred, H. R.; Pickel, F. H.; and Cox, A. J. 1979. Homeostatic Utility Control. In *IEEE PES Summer Meeting*. Vancouver, Paper F 79 685 9.

[3] Outhred, H. R. and Schweppe, F. C. 1980. Quality of supply pricing for electric power systems. In *IEEE PES Winter Power Meeting*. New York, February, Paper A 80 084-4.

[4] Schweppe, F. C.; Tabors, R. D.; and Bohn, R. E. 1988. *Electricity Spot Pricing*: Kluwer Academic Publishers.

[5] Kaye, R. J. and Outhred, H. R. 1989. A theory of electricity tariff design for optimal operation and investment. *IEEE Transactions on Power Systems* 4: 606-613.

[6] Pamudji, N. 1995. Modelling network effects in a competitive electricity industry. Master of Engineering thesis, School of Electrical Engineering & Telecommunications, University of New South Wales, Sydney.

[7] Kim, S. G.; Outhred, H. R.; and MacGill, I. F. 2004. Commercialising Voltage Regulation in Nodal Electricity Spot Markets. *To be presented Conference on Electricity Supply Industry in Transition: Issues and Prospects for Asia*. AIT, Bangkok, 14-16 January.

[8] Outhred, H. R. 2003. Some strengths and weaknesses of electricity restructuring in Australia. In *Proceedings of the IEEE PowerTech03 Conference*. Bologna, Italy, June.

[9] Outhred, H. R. 2003. The evolving Australian National Electricity Market: an assessment. *To appear in Power progress: an audit of Australia's electricity reform experiment.*

[10] National Electricity Code Administrator (NECA). 2002. The performance of the National Electricity Market. www.neca.com.au.

[11] Australian Competition and Consumer Commission. 2003. Discussion paper: Review of the regulatory test. 5 February, www.accc.gov.au.

[12] Intelligent Energy Systems. 2002. Economics and co-existence of regulated and nonregulated transmission. A report to the ACCC, September, www.accc.gov.au.

[13] Littlechild, S. 2003. Transmission regulation, merchant investment, and the experience of SNI and Murraylink in the Australian National Electricity Market. www.ksg.harvard.edu/hepg.

[14] National Electricity Market Management Company. 2003. Statement of Opportunities. www.nemmco.com.au.

[15] Independent Pricing and Regulatory Tribunal (IPART). 2003. Inquiry into the role of demand management and other options in the provision of energy services. Final report, October, www.ipart.nsw.gov.au.

[16] Council of Australian Governments. 2002. Energy market review final report. December, www.energymarketreview.org.

[17] National Electricity Market Ministers' Forum. 2003. Transmission regulation terms of reference.

[18] Australian Business Council for Sustainable Energy. 2003. Guide for the connection of embedded generation in the National Electricity Market. www.bcse.org.au.