Ancillary services & their treatment in the NEM

Fundamentals of the Australian Competitive Electricity Industry
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Trading in electricity: an abstraction from reality

- Main commercial markets
- Economic models
- Engineering models
- Physical electricity industry

Externalities

Ancillary services

Regulation & policy
A model of electricity trading

- Spot market energy traded as a commodity:
  - Energy (that meets QOS criteria) traded during each (short) spot market interval

- Financial instruments:
  - Related to future spot market prices:
    - Convey expectations of future spot market behaviour
    - Allow risk management

- Ancillary services:
  - To manage availability & quality of supply
Managing quality of supply

- ‘Quality of Supply’ (QOS) attributes:
  - Voltage, frequency, waveform purity, phase balance, supply availability at each node

- Managed by:
  - ‘Ancillary services’ (AS) in the short term:
    - Appropriate resources under automatic control
    - Projections of future supply-demand balance
    - Investments in new resources as required

- Via appropriate commercial arrangements
Key attributes from the perspective of operation & control

- **Size & location:**
  - Small resources may only be useful locally

- **Flexibility & responsiveness:**
  - Start time (hot & cold), ramp rate limit (up/down)

- **Cost structure:**
  - Start & operating cost (often non-linear)

- *In traditional power system, assume data is “objectively correct”*

- *In a restructured industry, assume data biased & use competitive pressure to “reveal preferences”*
### Indicative control capabilities

<table>
<thead>
<tr>
<th>Technology</th>
<th>Controllable?</th>
<th>Start-up time</th>
<th>Ramp-rate limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam cycle</td>
<td>Yes</td>
<td>5-24 h</td>
<td>+5%/min</td>
</tr>
<tr>
<td>CT</td>
<td>Yes</td>
<td>5 min</td>
<td>+20%/min</td>
</tr>
<tr>
<td>Hydro</td>
<td>Yes</td>
<td>1 min</td>
<td>+50%/min</td>
</tr>
<tr>
<td>Wind</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Solar</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Load</td>
<td>Yes</td>
<td>1 sec</td>
<td>100%/sec</td>
</tr>
</tbody>
</table>
Demand-side participation & projected low reserve conditions (NEMMCO SOO Executive Summary, 2004)

### Table 4 Demand-side Participation (MW)

<table>
<thead>
<tr>
<th>State</th>
<th>Committed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland</td>
<td>157</td>
</tr>
<tr>
<td>New South Wales</td>
<td>14</td>
</tr>
<tr>
<td>Victoria/South Australia</td>
<td>163</td>
</tr>
<tr>
<td>Tasmania</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 5 Projected Low Reserve Conditions

<table>
<thead>
<tr>
<th>State</th>
<th>LRC Point</th>
<th>Reserve Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland</td>
<td>2009/10</td>
<td>132 MW</td>
</tr>
<tr>
<td>New South Wales</td>
<td>2008/09</td>
<td>157 MW</td>
</tr>
<tr>
<td>Victoria/South Australia</td>
<td>2004/05¹</td>
<td>356 MW</td>
</tr>
<tr>
<td>(combined)</td>
<td>2006/07</td>
<td>321 MW</td>
</tr>
<tr>
<td>Tasmania</td>
<td>Beyond 2013/14</td>
<td>–</td>
</tr>
</tbody>
</table>
Managing supply-demand balance in NEM

Spot market forecast & derivative markets

Commercial issues

Physical issues

Supply/demand projections & FCAS derivative markets

Increasing uncertainty

Spot market for period t

Spot market for period t+1

Spot period t

Spot period t+1

Frequency control ancillary service markets for period t

FCAS markets for period t+1
AS acquisition & actuation markets

Offers to provide ancillary services

Acquisition markets

Accepted offers

Actuation markets

Outcomes from the technical forward & spot markets

Forecasts of system operation and market conditions

Triggers, rewards, penalties

Providers of services
AS Acquisition market design

- Offer to provide a service:
  - Capability statement, e.g:
    - max, min & rate of change limits
    - required lead time (starting time)
    - Minimum running time
    - dependence on acceptance of spot offer
  - ‘Willingness to provide’ functions:
    - for readiness
    - for actuation
  - Valid time period of offer
AS Actuation market design

- Mainly by automatic control functions, e.g:
  - Governor, voltage regulator, AGC, economic dispatch, transformer tap changers
- Same market interval as spot market
- Requirement determined by evolving system operation:
  - Notify market participants of evolving conditions in real time to enhance responsiveness
AS Actuation market design

- Initialised by outcomes of AS acquisition & spot markets:
  - Determine parameters & set points for control systems
  - Accepted spot market quantities provide a basis for assessing participants’ AS activity
- Financial outcome resolved after the relevant spot market closes
Potential for commercial trading

- Voltage, frequency, short term availability:
  - ✔ Competition to provide services (technical efficiency)
  - ✔ Willingness to pay for services (allocative efficiency)
  - ✔ Transition to a spot market solution if need is prolonged

- Power system security:
  - ❓ Market valuation of security
  - ❓ Competition to provide services
Potential for commercial trading

- Waveform purity & phase balance:
  - Potential for competition in provision in service
  - Standards likely to define target outcome
  - Payment likely to be by regulated cost allocation

- Potential reduction in QOS requirements:
  - Short-term QOS excursions often acceptable:
    - 1% voltage reduction causes ~ 1% load reduction
    - 1% frequency reduction causes ~ 2% load reduction
  - Consumers may find cost effective alternatives:
    - uninterruptible power supplies, insurance
Physical vs financial risk management

- Ancillary services are physical means for risk management

- ‘Financial instrument’ alternatives, e.g:
  - Insurance against damage caused by loss of QOS
  - Call options used to finance rapid start generators:
    - could operate in both spot & ancillary service markets

- Such alternatives enhance contestability in the provision of ancillary services
NEM definition of ancillary services
(a wholesale market approach)

- Those services that provide for:
  - Power system security
  - Quality of supply
  - Enhanced spot trading benefits:
    - Where not provided on the basis of spot prices alone

- NEM categories of ancillary service:
  - Frequency control ancillary services (FCAS)
  - Network control ancillary services (NCAS)
  - System restart ancillary services (SRAS)
Cost of NEM ancillary services in 1999

- Overall cost ~ $130 Million pa (1999):
  - Less than 1% of the delivered cost of electricity
- Breakdown of NEM ancillary service costs:
  - Frequency control ancillary services: ~65%
  - Network control ancillary services: ~25%
  - System restart ancillary services: ~10%
NEM frequency control ancillary services

- Frequency management - small deviations:
  - Maintain frequency within normal band & control time error
  - Two markets (raise & lower regulation) from 10/01

- Frequency management - large deviations:
  - Large step changes in demand
  - Loss of largest single generator
  - Multiple contingencies
  - Six markets from October 2001: 6 sec; 60 sec; 5 min raise & lower
FCAS cost $/week before & after 10/01
(Performance of the ancillary service markets, NECA May 03)

FCAS ancillary services around 50% of total AS cost since 10/01
FCAS cost 10/01-3/03: sourced globally (top) & by region (bottom)  
(Performance of the ancillary service markets, NECA May 2003)
NEM FCAS market outcomes
April-June 2004
(NECA 04Q2 stats, 2004)
Review of FCAS markets

- ACCC determination on Regional Pricing of Ancillary Services, 17/9/03:
  - Participants in each region will bear costs when prices set by region
  - NECA to undertake a broader review

- Theoretical underpinnings of current FCAS arrangements appear to be weak
Relationship between main commercial markets & physical reality

**Main commercial markets**
- Spot & FI markets:
  - Set commodity targets for ancillary services
  - Manage persistent physical disturbances
  - Manage commercial disturbances

**Physical reality**
- Ancillary services:
  - Direct physical behaviour towards future energy targets
  - Reject physical disturbances
  - *Sufficient for expected tasks*

Projected cost of meeting future targets

Commercial disturbances

Physical disturbances
frequency control & NEM 5-30 minute spot market

Long term (>5 min) power imbalances resolved by hybrid 5-30 minute spot market

Offers to sell & bids to buy with ramp-rate limits

Market clearing price & accepted quantities for each participant

Medium term (10sec - 5 min) power imbalances controlled by centralised AGC

Automatic generation control algorithm distributes raise/lower signals to AGC participants

Power setpoints

Short-lived (<10 sec) power imbalances controlled by decentralised governors (local speed/frequency control)

Generator with speed governor

Generator with speed governor

Frequency-sensitive load

Unresolved disturbances
A generator responding to dispatch & small disturbance frequency control

- Energy target for next spot market
- Linear ramp from previous ave power level
- Generator power set-point
- Actual generation
- Shaft speed (frequency) errors
- AGC processing & filtering
- Frequency error
- Time error

\[ \sum \text{generator power set-point} \]

\[ \sum \text{actual generation} \]

\[ \sum \text{shaft speed (frequency) errors} \]
A generator tracking five-minute dispatch targets with AGC raise/lower bounds
Finite horizon ramping control (Samuelsen, 2001)

Spot market target & produced power for The Total, G1, G2, G3 and G4 (MW)
Large disturbance frequency control: loss of NSW 660 MW Generator
(source: NEMMCO)

Frequency control capability requirement = R

Maximum Power Input = 630 MW (nett of unit auxiliary load)

Return to normal frequency band >49.9 Hz within 5 min by AGC

Maintain frequency in tolerance band > 49.5 Hz by local governor action
Indicative AS response to a unit outage

- MW error
- 60 second response
- 6 second response
- 5 minute dispatch response
- 5 minutes
## NEM frequency tolerance bands

<table>
<thead>
<tr>
<th>State</th>
<th>Frequency band (Hz)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>49.85 Š 50.15 (99% of time)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>49.75 Š 50.25 (1% of time)</td>
<td></td>
</tr>
<tr>
<td>Single generator contingency</td>
<td>49.5 Š 50.5</td>
<td></td>
</tr>
<tr>
<td>Other credible contingency</td>
<td>49.0 Š 51.0</td>
<td></td>
</tr>
<tr>
<td>Emergency</td>
<td>47.0 Š 52.0</td>
<td></td>
</tr>
</tbody>
</table>
Distribution of frequency in the NEM, June 2003
(Reliability Panel Annual Report, 2002-3)
Frequency events outside the normal operating band in the NEM due to contingencies, 2002-03
(Reliability Panel Annual Report, 2002-03)
Power system disturbance, Friday 13/8/04

Current transformer failure at 2142 caused 6 generators to trip with loss of ~3100 MW of generation. Frequency fell to 48.9Hz, ~2100 MW load shed

<table>
<thead>
<tr>
<th>Generating unit</th>
<th>Output MW</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayswater unit 1</td>
<td>658</td>
<td>Generator Differential Protection</td>
</tr>
<tr>
<td>Bayswater unit 2</td>
<td>654</td>
<td>Generator Differential Protection</td>
</tr>
<tr>
<td>Bayswater unit 3</td>
<td>659</td>
<td>Generator Differential Protection</td>
</tr>
<tr>
<td>Vales Point unit 6</td>
<td>542</td>
<td>Excitation Protection</td>
</tr>
<tr>
<td>Eraring unit 2</td>
<td>424</td>
<td>Negative Phase Sequence</td>
</tr>
<tr>
<td>Redbank</td>
<td>150</td>
<td>Under Frequency and Under Voltage</td>
</tr>
</tbody>
</table>

![Graph showing frequency and load shedding](http://www.nemmco.com.au/operating/systemops/232-0020.htm)
Responses by generation and load

<table>
<thead>
<tr>
<th>Region</th>
<th>Load Block</th>
<th>Load Shed (MW)</th>
<th>Region Total (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>Pasminco Port Pirie</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Block 2 (SA Water)</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>VIC</td>
<td>1st Alcoa Portland Pot Line</td>
<td>279</td>
<td>488</td>
</tr>
<tr>
<td></td>
<td>Alcoa Pt. Henry Pot Line</td>
<td>119</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V4 (Alcoa Pt Henry Pot Line)</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>NSW</td>
<td>Tomago No.1 Pot Line</td>
<td>296</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>Capral No. 1 Pot Line</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capral No. 2 Pot Line</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>QLD</td>
<td>Q1 (Ergon &amp; Energex Customers)</td>
<td>314-340</td>
<td>500 - 550</td>
</tr>
<tr>
<td></td>
<td>Q5 (Ergon &amp; Energex Customers)</td>
<td>186-210</td>
<td></td>
</tr>
</tbody>
</table>

Also ~350MW load tripped on under voltage

<table>
<thead>
<tr>
<th>Region</th>
<th>Initial Generation</th>
<th>Increase (as measured 1 minute after event)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QLD</td>
<td>5890</td>
<td>390</td>
</tr>
<tr>
<td>NSW</td>
<td>8960</td>
<td>-2800</td>
</tr>
<tr>
<td>VIC</td>
<td>6465</td>
<td>200</td>
</tr>
<tr>
<td>SA</td>
<td>1150</td>
<td>145</td>
</tr>
<tr>
<td>Snowy</td>
<td>100</td>
<td>330</td>
</tr>
</tbody>
</table>

Net loss of generation then ~1900MW, approximately equal to reduction in load
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5-minute demand & price graphs for the day of the disturbance (www.nemmco.com.au)

NSW1 5 minute Demand and Price for period 13/08/2004 00:00 to 14/08/2004 14:20

~900MW

VIC1 5 minute Demand and Price for period 13/08/2004 00:00 to 14/08/2004 14:20

~600MW

QLD1 5 minute Demand and Price for period 13/08/2004 00:00 to 14/08/2004 14:20

~600MW
**Network Control Ancillary Services (NCAS)**

- **Voltage control - continuous:**
  - NEC requires tap changers

- **Voltage control - contingency:**
  - Reactive power resources for planned worst case conditions
  - Emergency schemes for plausible multiple contingencies

- **Stability control**
  - NEC requires generators to install stabilisers
    - To enhance small & large disturbance stability
Network Control Ancillary Services (continued)

- Network loading contingency control:
  - To control transmission line flows
  - To permit full utilisation of transmission lines

System Re-start Ancillary Services

- Power station self-start capability
- Early restoration of supply to major cities
A distribution network perspective on ancillary services

- Transmission level ancillary services have little impact on distribution network QOS:
  - Voltage regulation, waveform purity, phase balance & supply availability

- Distribution level ancillary services may also address transmission level QOS:
  - e.g. frequency & stability-related services

- Thus distribution-level AS may have greater value than transmission level AS
Quality of supply in distribution networks

- Quality of supply attributes (QOS):
  - Voltage, frequency, waveform purity
  - Supply availability

- Practical network can’t achieve perfect QOS:
  - Supply availability can vary widely within distribution networks
  - Poor QOS can cause electrical equipment to malfunction
  - Customer equipment can affect QOS
Energy density & reliability of NSW Distributors (IPART, 1996/97)

![Bar chart showing energy density and average outage time for different distributors in NSW.](chart)

- **Australian Inland Energy**
- **Advance Energy**
- **Northpower**
- **Great Southern Energy**
- **Integral Energy**
- **Energy Australia**

**MWh per circuit km**

**Ave outage time (min/yr)**
Average reliability in EnergyAustralia regions
(EnergyAustralia Electricity Supply Standards, 1998)
IPART’s recommended guaranteed customer service standards (IPART, 2004)

- Compensate customers on application if the number of outages per financial year exceed:
  - For EnergyAustralia & Integral:
    - 9 for customers on urban feeders
    - 15 for customers on rural feeders
  - For Country Energy & Australian Inland Energy:
    - 12 for customers on urban feeders
    - 20 for customers on rural feeders

- Compensate all DNSP customers on application if an individual outage exceeds 12 hours

- Up to a limit of 4 payments per year per customer
Average voltage dip events in EnergyAustralia service territory

(EnergyAustralia Electricity Supply Standards, 1998)
One piece of electrical equipment may interfere with another

“There goes that damn electric chair again!”
Conclusions

- Ancillary services are an essential part of a competitive electricity industry:
  - Required to maintain availability & quality of supply
  - Critical in determining the need for investment

- AS most important at consumer nodes:
  - Primarily distribution rather than transmission issue
  - AS presently dealt with at the wholesale level:
    - Bias towards large participants

- Australian approach to AS is still evolving:
  - Unresolved issues include boundary problems