Experience with Market-Based Ancillary Services in the Australian National Electricity Market

Stuart Thorncraft, s.thorncraft@ieee.org
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Outline

- brief overview of Australian National Electricity Market (NEM)
- key features & design choices of the NEM market-based ancillary service arrangements
- outcomes of the market-based ancillary services to date
- comment on strengths & weaknesses
Key Features of Australia’s NEM

- regional market model covers south-eastern states
- compulsory participation for generators >= 30MW
- 5-min regional gross pool electricity spot market LP:
  - energy pricing & dispatch (based on generation offers, demand-side bids & load forecast)
  - market-based frequency control ancillary services are simultaneously priced and ‘enabled’ for 8 service types
  - many linear security constraints
- offers and bids for energy services and ancillary services can be revised as required (effectively no gate closure)
- all prices capped at $10,000/MWh
- inputs & outputs for all market processes including 5-minute spot market are published either immediately after calculation or the following day

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Ancillary Services in the NEM

- Frequency Control Ancillary Services (FCAS)
  - maintain frequency close to 50Hz
  - market-based arrangements commenced Sept. 2001
- Network Control Ancillary Services (NCAS)
  - management of voltage magnitude & network power flows
  - non-market AS (long-term contracts)
- System Restart Ancillary Services (SRAS)
  - restart the system (or part thereof) following blackout
  - non-market AS (long-term contracts)

FCAS Responsibilities

- AEMC (Australian Energy Market Commission)
  - specifies power system frequency standards
  - assesses NEMMCO’s performance in satisfying standards
- NEMMCO (Market & System Operator)
  - maintain secure power system
  - purchase sufficient ancillary services to achieve this
  - charge cost back to market participants
  - monitor system performance & verify service delivery
- Market participants
  - deliver ancillary services if required
### Experience with Market-Based Ancillary Services in the Australian NEM

#### Defining Frequency Control Ancillary Services (FCAS)

<table>
<thead>
<tr>
<th>Service class</th>
<th>Service name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>regulation</td>
<td>regulation raise</td>
<td>continuous correction of small freq. deviations – AGC manages it</td>
</tr>
<tr>
<td></td>
<td>regulation lower</td>
<td></td>
</tr>
<tr>
<td>contingency</td>
<td>raise 6s (fast raise)</td>
<td>arrest a large frequency deviation – governor response &amp; under-frequency load shedding</td>
</tr>
<tr>
<td></td>
<td>lower 6s (fast lower)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>raise 60s (slow raise)</td>
<td>stabilise and commence correction of frequency following large frequency deviation</td>
</tr>
<tr>
<td></td>
<td>lower 60s (slow lower)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>raise 5m (delayed)</td>
<td>response to return the system to the normal frequency band – rapid unit loading &amp; unloading</td>
</tr>
<tr>
<td></td>
<td>lower 5m (delayed)</td>
<td></td>
</tr>
</tbody>
</table>

- **FREQUENCY**
  - regulation (AGC)
  - fast raise / 6s raise (arrests – e.g. governor response)
  - slow raise / 60s raise (initial correction)
  - delayed raise / 5m raise (e.g. rapid unit loading)

- **normal band standards:** 49.85-50.15 for 99% time

- e.g. triggered by an unplanned generator outage (contingency)
**NEM Spot Market – inputs & outputs for FCAS**

- **market participants**
- **FCAS offers**
- **NEM Dispatch Engine** (LP optimization)
- **5-minutes**
- **AGC frequency regulation**
- **NEMMCO**

### FCAS offers
- up to 8 FCAS MW enablement levels per resource
- regulation raise & lower MW enablements

### NEM Dispatch Engine
- **FCAS MW requirements**
  - global requirements
  - local requirements

### 8 FCAS prices
- computed on regional basis
- using global & local requirement shadow prices
- used for FCAS spot revenues
- used in FCAS cost recovery

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**Setting FCAS Requirements**

<table>
<thead>
<tr>
<th>Service class</th>
<th>Service name</th>
<th>Requirement setting process</th>
</tr>
</thead>
<tbody>
<tr>
<td>regulation</td>
<td>regulation raise &amp; regulation lower</td>
<td>Set on a trial &amp; error basis where each month the performance of the system is assessed and levels increased accordingly.</td>
</tr>
<tr>
<td>contingency</td>
<td>raise 6s, 60s, 5m</td>
<td>Based on the largest generator contingency less an allowance for load relief. For 5m trade-off between raise regulation.</td>
</tr>
<tr>
<td></td>
<td>lower 6s, 60s, 5m</td>
<td>Based on the largest load block that could fail less an allowance for load relief. For 5m trade-off between lower regulation.</td>
</tr>
</tbody>
</table>

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9

10
Example of Raise FCAS Requirements

- Regulation requirements increased for time-error correction.
- Contingency requirements reflect largest generator less load relief.

Largest Generator Contingency Duration Curves

- Largest credible contingency in Tasmania – set local requirement to ensure frequency corrected using resources only from within Tasmania region if outage occurs.
Interface between market & control systems

NEM Dispatch Engine

ramping signal generator

regulation raise enablement

regulation lower enablement

energy target

frequency error

time error

filtering & processing

regulation requirement (RR)

switching rule:

RR*LRPF_i if RR > 0 or RR*RRPF_i o/wise

generator i power set point

sum RE_i

RRPF_i = \sum RE_i

sum LE_i

LRPF_i = \sum LE_i

Regulation Requirement Profile

early morning ramping

high demand & evening ramp-down
30-minute trading & observed frequency deviation pattern

FCAS spot revenue
- FCAS service providers are only paid for enablement – no usage payments
- FCAS revenue is resolved on 5-minute basis:

$$\text{FCAS Revenue} = \frac{\text{FCAS Price} \times \text{FCAS Enablement}}{12}$$

- FCAS costs recovered from NEM participants
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FCAS revenue streams (13/8/04)

- FCAS revenue (daily-averages since '01)

3100MW of generation lost, frequency to 48.9Hz, ~2100MW of load lost

FCAS raise prices (daily-averages since ‘01)
Raise FCAS average daily price profile

daily cyclic mean calculated for June 06 – June 07

FCAS lower prices (daily-averages since ‘01)
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Lower FCAS average daily price profile

- Lower FCAS average daily price profile
- Daily cyclic mean calculated for June 06 – June 07
- Baseload plant avoiding going below min stable levels
- High demand in afternoons & evenings

Market interface for FCAS providers

- Source: Intelligent Energy Systems
FCAS participation

- generally more participants have installed necessary control systems & entered into the FCAS markets
- rebidding in FCAS occurs frequently – gaming vs. management of technical issues?

<table>
<thead>
<tr>
<th>Fuel source</th>
<th>Lower regulation average enablement (%)</th>
<th>Lower regulation average enablement (%)</th>
<th>Raise contingency average enablement (%)</th>
<th>Lower contingency average enablement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Coal</td>
<td>38%</td>
<td>43%</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>Brown Coal</td>
<td>9%</td>
<td>16%</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Hydro</td>
<td>45%</td>
<td>36%</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>Gas / Oil</td>
<td>8%</td>
<td>6%</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>

calculated for calendar year 2006

Entry into FCAS markets up to ‘03

source: NECA
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Number & duration of Frequency Events FY 04/05

- Outworking of AEMC reliability / security monitoring process

FCAS cost Recovery

- Raise contingency services
  - cost of 3 raise contingency services split between generators based on metered energy

- Lower contingency services
  - cost of 3 lower contingency services split between loads based on metered energy

- Regulation service costs
  - split between generators & loads based on ‘causer-pays’
  - 4s SCADA data processed to identify generators & loads that gave rise to need for frequency regulation
  - fraction of cost calculated using correlations between deviations from spot market targets (or lines of best fit) & regulation control signal
Observations of FCAS costs

- very low ~ 0.4% of market turnover
- significant part of costs associated with rare-events where prices increase dramatically due to network outages requiring local sourcing of service providers (smaller pool of resources)
- generally declined over time, numerous factors:
  - NEMMCO has refined algorithm with time which has generally increased level of co-optimization
  - increased number of service providers
  - increased interconnection in the NEM (QLD & TAS regions) increased pool of providers
  - participants better able to manage trade-offs between FCAS & energy

FCAS Costs for FY 05/06

<table>
<thead>
<tr>
<th>FCAS</th>
<th>$31m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>$7,120m</td>
</tr>
</tbody>
</table>

Source: NEMMCO
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Market Ancillary Service Costs since ‘05

- Arrangements have resulted in very low FCAS costs
- Very few incidents where frequency standards have been breached
- Generally a robust set of arrangements that have worked during large disturbances (e.g. Jan 16 ‘07)
- Clear assignment of roles, responsibilities & principles
- Processes in place to improve efficiency of existing arrangements where possible
- Services offered by broad different types of generators (hydro, gas-fired, coal-fired)
Weaknesses

- only market-based arrangements exist for frequency control (e.g. voltage & other ancillary service markets could be envisaged)
- arrangements have increased complexity of spot market trading
- mismatch between FCAS model & physical reality
- boundary issues between services & market vs. AS
- minimal demand-side participation & generators connected to the LV portion of grid
- lack of hedging instruments for FCAS