Ancillary services and power system security in the NEM

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Ancillary services link commercial markets with physical E1
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
## 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>
Timeline for electricity trading
(requires active demand-side participation)

Financial instrument (FI) trading & spot market projections

Spot market for period t

Interactions & constraints

Spot market for period t+1

Forward-looking ancillary service (AS) “acquisition markets”

ancillary service “actuation markets” for period t

Increasing uncertainty

Spot market for period t+1

ancillary service “actuation markets” for period t+1

CEEM Training Program – EI Restructuring in Australia
AS acquisition & actuation markets

- Offers to provide ancillary services
  - Acquisition markets
    - Accepted offers
      - Outcomes from the technical forward & spot markets
        - Triggers, rewards, penalties
          - Providers of services
          - Forecasts of system operation and market conditions
            - Actuation markets
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

- Initialised by outcomes of AS acquisition & spot mkts:
  - Determine parameters & set points for control systems
- Acts mainly by automatic control functions, e.g:
  - Governor, voltage regulator, AGC, economic dispatch, transformer tap changers
- Same market interval as spot market
- Requirement det. by evolving system operation:
  - Notify market participants of evolving conditions in real time to enhance responsiveness
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
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)
Power system security definitions
(National Electricity Code Chapter 4)

• Satisfactory operating state:
  – Frequency “normal” (49.9-50.1Hz), except for brief excursions within 49.75-50.25Hz
  – Voltage magnitudes within specified limits
  – All equipment operating within equipment rating
  – All plausible fault currents within breaker ratings

• Contingencies (equipment outages):
  – Credible, eg single generator or network element
  – Non-credible, eg multiple outages except in abnormal conditions, eg severe weather, bush fires
Power system security definitions ctd
(National Electricity Code Chapter 4)

• Secure operating state:
  – Currently in a satisfactory operating state
  – Would return to a satisfactory operating state following any single credible contingency:
    • Non-credible contingencies can sometimes become credible, eg SA-Vic Heywood double circuit trip during lightning activity

• Technical envelope:
  – Boundary surface of secure operating states:
    • Which depends on load forecasts, equipment capabilities and their current operating constraints
Power system security tasks & states
(National Electricity Code Chapter 4)

• Maintaining power system security:
  – Keep power system in a secure operating state
  – Return to a secure operating state as soon as possible
    following a non-credible contingency
  – If necessary to maintain security, shed load if frequency
    is outside the normal operating frequency excursion
    band (49.75-50.25Hz)

• Reliable operating state:
  – No load has been or is expected to be shed
  – Reserves adequate for at least next 12 weeks
NEM frequency control ancillary services

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation Raise</td>
<td>Fast Raise and Fast Lower (Six second response to arrest the immediate frequency deviation)</td>
</tr>
<tr>
<td>Regulation Lower</td>
<td>Slow Raise and Slow Lower (Sixty second response to keep the frequency within the single contingency band)</td>
</tr>
<tr>
<td></td>
<td>Delayed Raise and Delayed Lower (Five minute response to return the frequency to the Normal Operating Band)</td>
</tr>
</tbody>
</table>

![Diagram showing 8 FCAS MW Requirements, FCAS Offers, SPD, 8 FCAS Clearing Prices, FCAS Enablement Targets]
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

- Frequency error
- 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

Unresolved disturbances
NEM frequency tolerance bands

<table>
<thead>
<tr>
<th>State</th>
<th>Frequency band (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>49.85 Š 50.15 (99% of time)</td>
</tr>
<tr>
<td></td>
<td>49.75 Š 50.25 (1% of time)</td>
</tr>
<tr>
<td>Single gene rator contingen cy</td>
<td>49.5 Š 50.5</td>
</tr>
<tr>
<td>Other credible contingen cy</td>
<td>49.0 Š 51.0</td>
</tr>
<tr>
<td>Emergency</td>
<td>47.0 Š 52.0</td>
</tr>
</tbody>
</table>
Large disturbance frequency control: loss of NSW 660 MW Generator

Frequency control capability requirement = R

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

- 50.0 Hz
- 49.9 Hz
- 49.5 Hz

Maintain frequency in tolerance band > 49.5 Hz by local governor action

- \( R_{6s} \) (raise) = 430 MW
- \( R_{5m} \) (raise) = 630 MW less any load shedding included in 6 sec response which has not been restored

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

CEEM Training Program – EI Restructuring in Australia
Indicative AS response to a unit outage

- 6 second response
- 60 second response
- 5 minute dispatch response
Distribution of frequency in the NEM, June 2003
(Reiability Panel Annual Report, 2002-3)
Frequency events outside the normal operating band in the NEM due to contingencies, 2002-03

Number of events

Duration outside normal operating band (seconds)

CEEM Training Program – EI Restructuring in Australia
Transgrid transformer failure at 2142, 13/8/04 causes 5 generators to trip: frequency fell to 48.9Hz, ~2100 MW load shed in NSW, Qld & Vic (also some in SA) (www.nemmco.com.au)
NEM energy revenue, 13/8/04

20 Energy Revenue (All Regions)

Fri, 13 Aug 04

NSW1  QLD1  SA1  SNOWY1  VIC1
NEM FCAS revenue 13/8/04

32 FCAS Revenue (All Services)

Fri, 13 Aug 04

- LOWER5MIN
- LOWER60SEC
- LOWER6SEC
- LOWERREG
- RAISE5MIN
- RAISE60SEC
- RAISE6SEC
- RAISEREG
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
Power system security projections
(National Electricity Code Chapter 4)

• NEMMCO demand forecasts (indicative):
  – Daily forecasts to one week in 30 min intervals
  – Weekly forecasts to 2 years with daily profile
  – 10% probability of exceedence forecasts to be used for assessing reserve requirements

• Projected assessment of system adequacy:
  – Demand & supply-side forecasts:
    • Daily projection to one week (STPASA)
    • Weekly projection to two years (MTPASA)
Power system security projections ctd
(National Electricity Code Chapter 4)

• **Statement of opportunities (SOO):**
  – Prepared annually by NEMMCO to assess future need for additional generation, demand management or network augmentation

• **Annual National Transmission Statement:**
  – Identifies major transmission flow paths
  – Projects pattern of generation & demand
  – Assesses adequacy of transmission capacity
Dispatch, Pre-dispatch, PASA, SOO & ANTS
(source: NEMMCO)

Medium Term PASA (2 yr)

Short Term PASA (1 wk)

Pre-dispatch, re-bid & final dispatch schedule

0    day 1  day 2    week 1      month 1                      year 1        year 2

Statement of Opportunities (SOO) & Annual National Transmission Statement (ANTS) are intended to inform generation, demand & network investment decisions (10 year horizon, yearly update)

MT Projection of System Adequacy (PASA) is intended to inform near-term reliability assessment and reserve trader processes (2 year horizon, weekly update)