Improving hydro scheduling in a high non-synchronous penetration power system
an Australian experience
Tasmania

- Island state of Australia
- Connected to mainland via ~500 MW DC link
- 1200 MW average electricity demand
- Generation 82% hydro, 15% wind, 2% rooftop solar, 1% gas*
  - Hydroelectric generation owned & operated by Hydro Tasmania
- Hydro historically managed using heuristic-based models (both short & long-term)
  - Since 2021, implementing MILP & SDDP optimisation models

* Since newest wind farms commissioned in 2020
“National” Electricity Market
“National” Electricity Market

• Coal dominates – but retiring
  • Significant wind & solar
  • Significant behind-the-meter solar

• 40,000km of transmission
• 10,000,000 customers
• 54,000 MW capacity
• 180,000 GWh annual demand (operational)

• Energy-only spot market
  • Settled every 5 minutes
  • Cap = $15,000/MWh (~100,000 NOK)
  • Floor = -$1000/MWh (~-7000 NOK)
  • 8 frequency control ancillary services markets – co-optimised with energy
  • ALL energy bought & sold on spot market
  • Market participants use financial contracts to manage risks
Hydropower in the NEM

2020 utility-scale generation by fuel

- NEM
  - Thermal
  - Variable Renewable
  - Hydropower

- Tasmania
  - Variable Renewable

Source: OpenNEM.org
## Hydro Tasmania’s scheduling models

<table>
<thead>
<tr>
<th></th>
<th><strong>Existing</strong></th>
<th><strong>New / under development</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-term</strong></td>
<td>In-house heuristic-based “optimisation” (deterministic)</td>
<td>NCP short-term optimisation model (PSR) (deterministic)</td>
</tr>
<tr>
<td>(next few days)</td>
<td>In-house hydraulic simulation</td>
<td></td>
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<tr>
<td><strong>Long-term</strong></td>
<td>In-house heuristic-based simulation (300 replicates)</td>
<td>Plexos hydro optimisation model (Energy Exemplar)</td>
</tr>
<tr>
<td>(everything else)</td>
<td>Scenarios used for decision-making</td>
<td>SDDP hydro optimisation model (PSR)</td>
</tr>
</tbody>
</table>
Tasmanian hydrology

- Entirely rainfall-driven inflows
- Very seasonal - negative summer inflows
- Historical records to 1924
- Impact of climate change on seasonal patterns
  - Dryer autumns & summers
  - Timing of inflows hugely material to operational decision-making

- Range of storage sizes – 1/2hr to 3+ years
- 2 largest storages driven by different weather patterns
Negative market prices

Percent of half-hour intervals when the regional spot price was negative, Cal 2021

<table>
<thead>
<tr>
<th>Region</th>
<th>NSW</th>
<th>QLD</th>
<th>SA</th>
<th>TAS</th>
<th>VIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td>4%</td>
<td>7%</td>
<td>23%</td>
<td>13%</td>
<td>19%</td>
</tr>
</tbody>
</table>

- Price caps +$15 000 to -$1 000
- (+100,000 to -7000 NOK)
- Coal / inflexible generators want to avoid start/stop cost
- Renewable generators get renewable energy credits
Negative market prices

- For long- and short-term scheduling

- Linearisation techniques which assume positive price
  - E.g. pumped storage or battery incentivised to store and discharge at the same time
  - E.g. series of linear “>=” inequalities for losses
Synchronous condenser operation

- Very high inverter-based energy resources in Tasmania
  - DC interconnector ≈ 500 MW
  - Wind capacity = 568 MW
  - Solar (utility) capacity = 225 MW
  - Total > 1200 MW

- Operational demand
  - Min 900 MW
  - Average 1100 MW
  - Max 1700 MW

- Record 91.6% non-synchronous penetration (16 January 2021)
- Working towards 100% instantaneous penetration
- Support with synch con & low-load running of hydro generators (& gas)
Synchronous condenser operation

• For short-term scheduling only

• Third “binary” generator state (on, sc, off)

• Partial start-up costs

• System strength and/or inertia contribution (applies when “on” or “sc”)
  • Contributes to multi-machine constraints
Frequency Control Ancillary Services

- Australian NEM’s regulation & contingency services
- 8 (10) markets:
  - Regulation raise/lower
  - (1 second raise/lower - 2023)
  - 6 second raise/lower
  - 60 second raise/lower
  - 5 minute raise/lower
  - Anything longer than this is “energy” (5-minute spot market)
- Capability defined as trapezium
Frequency Control Ancillary Services

- 8 (10) frequency markets co-optimised with energy
- Trapezium defined as series of linear inequalities
- Initially optimising for minimum availability
  - Optimising bids later – shallow market
Update materiality

• 5-minute market
• Energy & FCAS offers updated any time
  • IF changes in demand, price, dispatch, plant condition
• Optimisation re-calculated at least every 5 minutes
• Provide trader with a recommendation – they need to respond
  • Can’t realistically do this for every plant every 5 minutes
  • Not a good look to toggle between similarly optimal options
Update materiality

![Graph showing materiality over time with two options: Option 1 and Option 2.]

- **Option 1**
- **Option 2**
Update materiality

Option 1

Option 2
Update materiality

Option 1

Option 2
Update materiality

• Only alert trader of material changes
  • Materiality ≠ magnitude

• Apply materiality/magnitude test to input assumptions
  • Very simple

• Apply small penalty for deviations from last accepted solution
  • More complicated, guarantees materiality

• Post-processing comparison of objective function
  • Only applies at system level
Bid discretisation & smoothing

• 10 price bands per “dispatch unit” per day
• Set the day before
• Can update volumes per price band at any time

• HT storage durations from < 1 hr to > 3 years
• Small storage marginal water value (opportunity cost) varies throughout day

• Cannot accurately dispatch these units (and meet water management requirements) with marginal price bids alone
Bid discretisation & smoothing

- NEM spot market is pay-as-cleared

- Bid small storages at low price to “guarantee” their dispatch at forecast optimal times

- Smooth generation ($\Delta$MW penalty) to avoid over-optimising (forecast accuracy)
  - Also reduces wear and tear
Thankyou
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