Coordinating Generation and HVDC Transmission Investment for Increased Renewables Penetrations in the NEM or How I Learnt to Love PLEXOS”

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Presentation Overview

- Context
- Methodology and Research Aims
- Building the Model
- Validating the Model
- Scenarios, Results and Conclusions
- Future Work
Context

- RE resources are geographically diverse.
  - Grid is largely based around existing fossil fuel generation
- Transmission system will become congested with new generation
  - Limits new generation connection to the network – slowing transition

Source: AEMO
Context – AEMO’s ISP

- Introduced the concept of Renewable Energy Zones (REZs)
- Included a transmission investment plan to transition to high renewable penetrations after coal closures

Source: AEMO, “Integrated System Plan”
Context

• Germany is considering using HVDC to reduce network constraints

Source: N. Storm, "Grid Development Plan 2030," 2017
Why HVDC and not HVAC?

• Less transmission losses, no skin effect
• Lower cost past critical distance
  • ~ 500 – 600 km
• Reduced land use

Source: ABB, “Powering the World” 2017
Methodology and Research Aims

1. Construct a multi-nodal representation of the NEM, allocating generators and loads to each relevant node.
2. Evaluate proxy intraregional constraints for within each region using existing NEM line capacity data.
4. Validate load and generation outputs with real data.
5. Conduct simulations for a base case (no future transmission builds) and long-term expansion planning (with future transmission builds).
Building the Model – Nodes & Load

• Split QLD and NSW into 3 separate nodes each

• Loads for each state region was split based on real peak demand data and forecasts at the substation level.
Building the Model – Transmission Lines

- Added intraregional capacity through existing lines
  - Consulted NEM SLD to identify relevant lines
  - Used Autumn/Spring Daytime Capacities

Source: AEMO, “NEM Single Line Diagram”
Building the Model – New HVDC Lines

• Added suite of transmission builds to interconnect the NEM
• Added in basic costs based on capacity and distance

<table>
<thead>
<tr>
<th>Line #</th>
<th>Connecting Nodes</th>
<th>Capacity (MW)</th>
<th>Distance (km)</th>
<th>Cost ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7 and 1</td>
<td>1500</td>
<td>1800</td>
<td>3510</td>
</tr>
<tr>
<td>9</td>
<td>7 and 2</td>
<td>1250</td>
<td>1500</td>
<td>2906</td>
</tr>
<tr>
<td>16</td>
<td>7 and 3</td>
<td>1500</td>
<td>1400</td>
<td>2836</td>
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<td></td>
<td>SA-QLD</td>
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</tr>
<tr>
<td>21</td>
<td>7 and 5</td>
<td>1750</td>
<td>1000</td>
<td>2214</td>
</tr>
<tr>
<td>26</td>
<td>7 and 6</td>
<td>1500</td>
<td>600</td>
<td>1488</td>
</tr>
<tr>
<td></td>
<td>SA-NSW (Riverlink)</td>
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</tr>
</tbody>
</table>
Building the Model - REZs

- Incorporated AEMO’s ISP REZs into the model
- Export capacity is lacking in key regions
  - 1 – North QLD
  - 5 – Eastern NSW
  - 7 – SA
  - 8 – VIC
  - 9 - TAS
Validating the Model - Loads

• Compared real and simulated demand profiles
  • Daily fluctuations apparent but profile is relatively accurate.

• Comparing real and simulated generation profiles
  • Obvious limitations due to hourly simulations
  • Real economic dispatch was not simulated
Validating the Model - Generation

• Real (Left) and simulated (right) SA generation for Oct 2018.
Validating the Model - Generation

• Real (Left) and simulated (right) NSW generation for Oct 2018.
Scenarios

• Base – no new transmission builds
• HVDC – new HVDC transmission builds
• ISP – includes new HVAC transmission builds
Results – HVDC Transmission

• New major transmission avenues built
  • North QLD – SA (1500 MW)
  • SA – NSW (1250 MW)

• New ‘support’ transmission to existing infrastructure
  • NSW – QLD (2000 MW)
  • NSW – VIC (1000 MW)
  • Basslink 2 [TAS – VIC] (1250 MW)

<table>
<thead>
<tr>
<th>Line</th>
<th>Capacity (MW)</th>
<th>Nodes Connected</th>
<th>Year</th>
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<tr>
<td>QLD - SA</td>
<td>1500</td>
<td>1 and 7</td>
<td>2024</td>
</tr>
<tr>
<td>SA – NSW</td>
<td>1250</td>
<td>5 and 7</td>
<td>2028</td>
</tr>
<tr>
<td>NSW – VIC</td>
<td>1000</td>
<td>6 and 8</td>
<td>2033</td>
</tr>
<tr>
<td>QLD – NSW</td>
<td>2000</td>
<td>3 and 5</td>
<td>2034</td>
</tr>
<tr>
<td>TAS – VIC (Basslink 2)</td>
<td>1250</td>
<td>8 and 9</td>
<td>2035</td>
</tr>
</tbody>
</table>
Results - Generation

• Significantly lower solar and utility scale storage costs lead to significant builds in later years (>2034)
• Minimal wind being built.
Results – Net Energy Flows

- New generation builds through coal closures in each state leads to changing energy flows
  - NSW is net importer of electricity especially after coal closures
  - QLD becomes a major exporter of electricity.
  - VIC transitions to net importer
  - TAS becomes net exporter
  - SA becomes net exporter due to increased interconnection to other states
Comparing Results Between Simulations

2039 Generation Mix

- HVDC
- Base
- ISP

2039 Generation Capacity

- HVDC
- Base
- ISP

Utilities represented:
- Utility Storage
- Wind
- Solar
- Hydro
- Natural Gas + Liquids
- Brown Coal
- Black Coal
Comparing Results Between Simulations

Generation Percentage Mix

- 2020 HVDC
- 2020 Base
- 2020 ISP
- 2039 HVDC
- 2039 Base
- 2039 ISP

2049 Generation Mix (Left) and Capacity (Right)

- HVDC - Mix
- BASE - Mix
- HVDC - Capacity
- BASE - Capacity

Legend:
- DFFG
- Renewables
- Storage

- RE
- Old Gas
- New Gas
- Storage
Conclusions

• NEM generation and capacity mix changes drastically with new REZs and utility storage

• Introduction of HVDC leads to reduced generation capacity built, in particular less new build gas and utility storage

• If HVDC lines are built, QLD becomes a major exporter of electricity.

• In the scenario of all coal retiring; HVDC enables greater RE penetrations with significantly reduced reliance on new gas and utility storage.
Future Work

• Add more nodes to further capture intraregional constraints
• Extending the grid:
  • Connecting to WA (~2.5hr sun time)
  • Connecting to South East Asia/ China as a net exporter of RE
• Explore physical characteristics of HVDC implementation and it’s effect on voltage and frequency management for operator
Questions

“It depends”