Moving Energy Through Time: Demand Response, Storage, Intermittency

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This talk is about ...

- We’ve been putting the spotlight on our research at the Energy Centre.
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- I’m under a strict mandate to have no equations in my talk.
- However the audience may ask questions the answers to which may include formulae!
Recurring themes

- Optimization (operations research): doing things smarter/more efficiently.
- Traditional OR takes deterministic inputs but the future is uncertain: most of my models involve a range of possible future outcomes.
- Optimization focuses on one agent, but “no man entity is an island”! So consider multiple agents and interactions: equilibrium modelling.
- The bulk of my efforts have been on electricity markets (NZEM), but I have an irrepressible desire to do math too! :)}
Why model uncertainty?

The State of the drunk at his AVERAGE position is ALIVE.

But the AVERAGE State of the drunk is DEAD.
NZEM in a snapshot

Clearing the market while meeting the **nodal** demand, with minimal total cost of generation while complying with **network constraints**. Hence we solve a side constrained **network optimization** problem.
Optimized dispatch over NZ
Industrial demand response

- Approximately 35% of NZ wide demand for electricity is consumed by large industrials who have some flexibility in reducing consumption.
- Price signals scarcity in any market, so when the price is high the market wants these participants to respond. These epochs coincide with generators of last resort (much more polluting).
- It is equally imperative for economic survival of their business that these industrials operate efficiently (e.g. load shift).
How many periods above $400.00 can we sustain ...?

Note that by cutting consumption, price is likely to reduce.
Huge price drop

Yet another significant piece of the price puzzle is ... reserves!
Lake level vs electricity prices (Jan 2008 to March 2014)
Examining a larger range
In the NZEM, we co-optimize energy and reserve dispatch, and to cover $N - 1$ risk, we ensure that the largest source of electricity supply is covered by reserve.

This implies that when the marginal generator is also the risk setter procuring one more unit of energy would require procuring one more unit of reserve as well.

Let $p_e$ denote the marginal offer price of energy and let $p_r$ be the price of reserve. The clearing price of electricity is then

$$\pi = p_e + p_r.$$ 

Take this into account and we will do much better (offer ILR).
How will this work in practice?

- How much should the industrial consume (or what to bid for consumption) and what to offer for ILR?
- Need to keep track of network effects.
- Decision making is wrapped around a multi-product auction.
- Involves uncertainty: rest of NZ consumption, generator offers, etc.
Simulation optimization

Price Distributions

Mode 1: 0MW
Mode 2: 5MW
Mode 3: 10MW
Mode 4: 15MW
Mode 5: 20MW
Mode 6: 25MW
Mode 7: 30MW
Mode 8: 35MW
Mode 9: 40MW
Mode 10: 45MW
Mode 11: 50MW
Mode 12: 55MW
Mode 13: 60MW
Mode 14: 65MW
Mode 15: 70MW
Mode 16: 75MW
Mode 17: 80MW
Mode 18: 85MW
Mode 19: 90MW
Mode 20: 95MW
Mode 21: 100MW
Mode 22: 105MW
Mode 23: 110MW

Nodal Price

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Constructing optimal consumption bid and ILR offers

- Capture this as a large (stochastic integer programming) model.
- Solve it cleverly (with tailored algorithms).
The proof of pudding is in the eating!

### Table 8  Policy performance—winter peak

<table>
<thead>
<tr>
<th>u</th>
<th>Optimal stack</th>
<th>Fixed quantity</th>
<th>Clairvoyant</th>
<th>Profit increase (%)</th>
<th>% of clairvoyant</th>
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<td>1702</td>
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<tr>
<td>Average</td>
<td>9532</td>
<td>7150</td>
<td>10565</td>
<td>29.8</td>
<td>88.9</td>
</tr>
</tbody>
</table>
This is great, but for one period ...!

- Thus far we’ve looked at consumption and ILR for one period.
- Industrials have contracts to fulfil over weeks or months.
- How should they bid for consumption and offer ILR, over a time horizon of weeks?
- This is an order of magnitude harder, but we have developed methodology and software to solve the problem.
- Paper forthcoming (but pre-print available upon request).
Case Study over a time horizon

Cost reduces by 16%.
Research support for DR

- We have been fortunate to have the support of MBIE and NSC7 for this body of work.
- I could not succeed without the continued support of the Energy Centre and the Energy Education Trust of NZ.
- But most importantly, the people: Geoff Pritchard, Mahbube Habibian, Nigel Cleland, Kazem Abbaszadeh, Tony Downward, Miguel Anjos, Michael Ferris, Mark Taylor, Basil Sharp, Milad Maralani, and many others.
Papers on DR


Other research on electricity markets

- A body of work on stochastic optimal dispatch.
- Be smarter and look at what may come ahead rather than a point forecast.
- Complete the market by embedding a market for flexibility.
- It also works demonstrably.
- Models for retailing: A basic retailer plus some insurance?
- Construction of distributions for offer stacks.
- And the list goes on!
Chewing the fat

Any comments or questions?