Market Simulation with Stochastic Hydro Thermal Power System Modelling

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Summary

- New Zealand power system
- Objectives of model
- Features to be modelled
- Modelling methodology
- Software structure

New Zealand Power System

- Approximately 70% hydro, with seasonal storage
- Thermal generation - coal, gas, oil
- Five large generation companies
- Electricity market - pool with nodal pricing
- Independent grid owner
- Separate local lines companies
- Electricity retailers, most owned by generators
- Price volatility, low inflow periods, transmission constraints, market power, illiquid derivatives

Model Objectives

- Developed for integrated generation - retail company
- Mid term planning
  - month ahead to 10 years ahead
  - weekly time steps
- Value at risk
- Fuel consumption forecasting
- Hydro reservoir management
- Marketing strategies, pricing
- New generation project analysis
- Policy responses

Features to be Modelled

- Hydro storage and stochastic inflows
  - Main driver of volatility
- HVDC link
  - Often constrains, significant losses
- Fuel supply arrangements
  - Several gas supplies, some take or pay
  - Limited total quantity on some gas contracts
- Fuel stockpiles
  - Coal stockpile as important as hydro reservoirs
- Hedges
- AC transmission constraints

Algorithm Overview

- Solve a stochastic LP of the generation system
  - 2 to 3 year horizon
- Pass information to the Cournot market simulation for the first week
  - plant capacity, costs of generation, demand, hedge levels
- Solve for Cournot equilibrium for one time period for peak, shoulder, off-peak, etc
- Pass results back to Mosel
  - quantity of generation, prices, demand
- Roll LP forward one week
  - update constraints, bounds
- Solve stochastic LP again, etc

Key Assumptions

- No inter period gaming
  - Stochastic LP is least cost, ignores influence of future gaming opportunities on hydro system water values
- Cournot is a reasonable representation of market participant behaviour in New Zealand
  - May not hold at very low prices as generators may set a floor on their prices
  - Political influence limits high prices, generators want to avoid heavy handed regulation
- Constant elasticity with price for Cournot model
  - Different elasticity for each load block and region
  - Lower elasticity at off peak times

Hydro Model

- Main purpose of stochastic LP is to produce water values
- Hydro water values treated as fuel cost for Cournot process
  - Hydro plant can then be treated as a thermal plant
- Minimum hydro specified
- Uncontrolled side flows impose a minimum hydro generation
  - Side flows must be utilised
  - Shaping of side flows determined by stochastic LP
- No spill unless physically essential
  - Regulator monitors spill to ensure no gaming

Stochastic LP

- Written in Mosel, Dash modelling language
  - Solved with Xpress-MP
- Inflow scenarios form a tree, with first period forming the trunk
- Each week more scenario branches appear
- Arrays structured with rows as scenarios, columns as time steps
- Branching has to be limited as problem can quickly become very large
  - Users know which years have high, low, average inflows
  - Select a sample which they are satisfied represent a range of outcomes

Cournot Problem

- Within a Mosel user written function
- Solves a set of non linear equations
  - Assume constant elasticity
  - Form a Lagrangian equation describing:
    - profit maximising condition for each company
    - power balance at each transmission system node
    - transmission link conditions at equilibrium
- Some companies treated as welfare maximisers
  - Generate when price exceeds marginal cost of generation
- Solve using a non linear solution algorithm
- Function evaluation for the non linear solver contains a small LP to allocate fuel to multi-fuel thermal plants

Alternative Approach

- Represent participant bidding behaviour directly by modelling bid structure in the stochastic LP
  - Repeatedly solve stochastic LP, roll forward in time
  - Offered as an optional mode of solving within the model
- Simple – no Cournot
- Gives user complete control of bidding strategies
- Results easier to understand
  - sometimes gives users more useful insight as the effects of changes to inputs are easier to understand, for an inexperienced user
- Faster especially when Cournot problems hard to solve
  - for low elasticities, a (practical) solution does not always exist

Alternative Approach (continued)

- Bid behaviour seems to be stable much of the time
  - Give a good representation of market when stable
- Disadvantages:
  - What happens when new generation commissions
  - Are there opportunities for creating transmission constraints
  - Will not find new opportunities for the model owner to change their bidding behaviour using model predictions
- More detailed representation of the physical power system is possible in the stochastic LP model
  - Unit commitment could be modelled in the Cournot Equilibrium model, but would be complex.
  - Some fuel supply issues difficult
- Provides a useful first step in modelling market behaviour