Using PLEXOS to Validate TIMES

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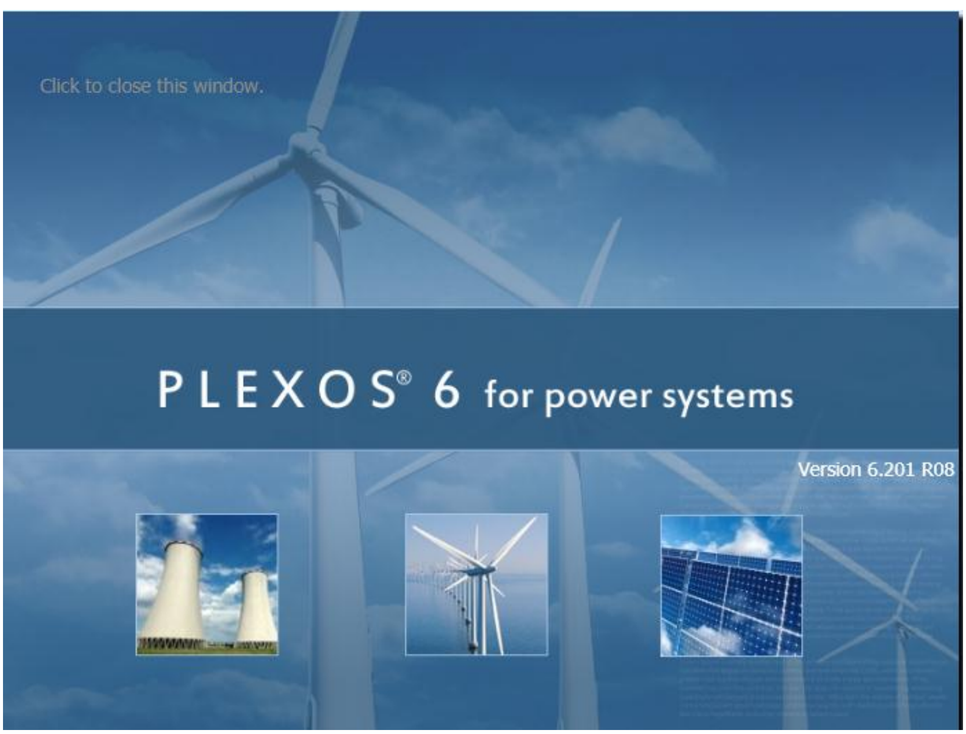
– Energy System Modelling-Alessandro Chiodi

Introduction

- This presentation gives a brief overview of the capabilities of the power systems modelling software PLEXOS and how we intend to use it to validate TIMES
- Research is intended to **compliment** TIMES modelling and to give insight into electricity modelling in TIMES
- Presentation includes slides by Dr Glenn Drayton Energy Examplar



Software

ENERGY EXEMPLAR
Power Market Simulation & Analysis Software

PLEXOS for Power Systems

- Commercial power system model with solutions based entirely on mathematical optimisation:
  - Linear Programming (LP)
  - Mixed Integer Programming (MIP)
  - Stochastic Optimisation (SO) (MISO)
- Used worldwide by all types of customers
- UCC use Xpress Solver from Dash Optimization

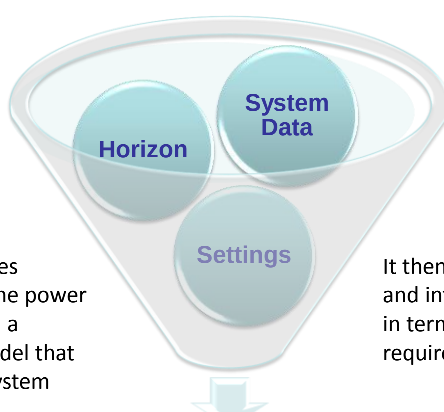
Types of Power System modelling within PLEXOS

1. **Capacity Expansion Planning**
2. Transmission Planning
3. Market Analysis
4. **Operational Modelling**
5. Portfolio Optimisation

What answers are they looking for?

Application	Results
Capacity Expansion Planning	Timing, location, and type of new generation and transmission investments (and retirements)
Transmission Planning	Requirement for and economic benefit of transmission upgrades. Ability of system to cope with proposed generation upgrades and forecast load growth.
Market Analysis	Electric power prices, generation and fuel forecasts, revenue and profitability of generators
Operational Modelling	Optimal timing of generator commitment (on/off decisions). Management of generation and fuel contracts and constraints, and emissions constraints.
Portfolio Optimisation	Operation of generating units and contracts to maximise profit

What does the PLEXOS model do?



The simulator takes input data from the power system and builds a mathematical model that represents that system

It then solves that model and interprets the solution in terms of the outcomes required by the user

Mathematical Model

Capacity Expansion Planning (CEP)

- Timing, location, and type of new generation and transmission investments (and retirements):
  - Thermal: gas, coal, nuclear
  - Renewables: wind, solar, tidal, geothermal, hydro
  - Transmission: AC network upgrades, HVDC
- Two types of costs:
  - Capital Costs: construction, financing
  - Production Costs: fuel, maintenance
- Optimise from perspective of system operator so include notional cost of unserved energy (outages) and reliability requirements (LOLP, capacity margin)

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CEP: Data Requirements

- **Load**: long-term forecast (energy and peak load and historical shape by hour/half-hour)
- **Thermal Generation**: fuel costs, capacities, efficiencies, operations and maintenance costs, operational constraints
- **Hydro**: energy limits, release constraints, pumped storage efficiencies, storage capacity and inflows
- **Wind**: wind speed profile, power curves
- **Transmission**: topography, constraints
- **New Generation**: known and potential, size, build cost
- **Retirement Candidates**: retirement cost
- **Transmission Upgrades**: size, cost

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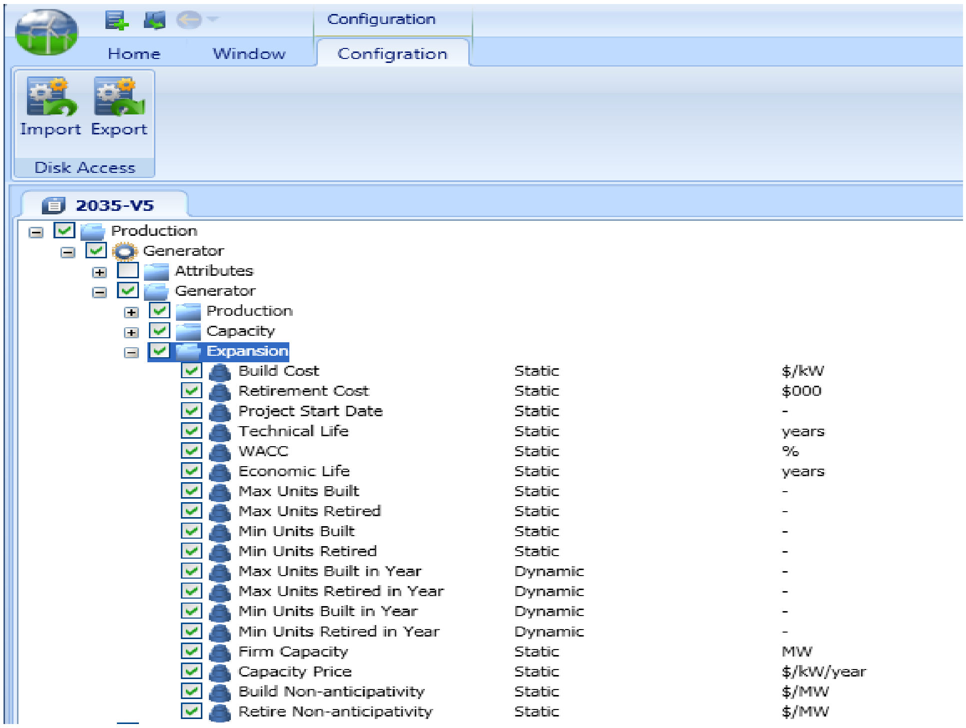
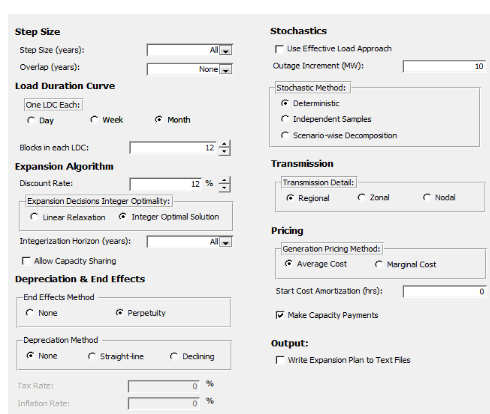


CEP: PLEXOS LT Plan

- “LT Plan” algorithm with Horizon 1-30+ years
- Options:
  - Simulation resolution
  - Transmission detail
  - Deterministic or stochastic optimisation
  - Treatment of tax and depreciation



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Stochastic Optimisation

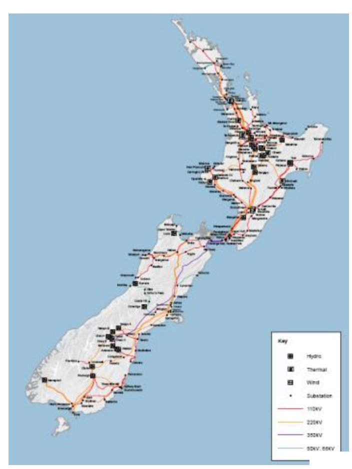
Stochastic Optimisation

- Stochastic modelling is a framework for modeling/optimization of problems that involve **uncertainty**
- Stochastic models take advantage of the fact that probability distributions governing the data are known or at least can be estimated
- The goal is to find some policy that is feasible for all (or almost all) the possible data instances and maximizes the expectation of some function of the decisions and the random variables.

Case Study
Capacity Expansion Model

CEP: Case Study

- System: New Zealand EM
- Client: Transpower NZ (ISO)
- Supply dominated by hydro in the South Island
- Load is in the North Island
- High-voltage DC (HVDC) interconnection between the two islands
- One half of the HVDC is being retired:
  - Should it be replaced?
  - If so, what size?
  - or new generation instead?



CEP: Case Study

- New transmission expensive, but limited thermal expansion options: coal too "dirty", natural gas supply very limited
- Renewable options:
  - Wind
  - Micro-hydro
  - Geothermal
  - Wave power
- Government targets 90% renewables by 2020
- Also consider demand-side participation
- Solved using 35 year PLEXOS LT Plan with mixed-integer programming (run time more than 2 hours each case)

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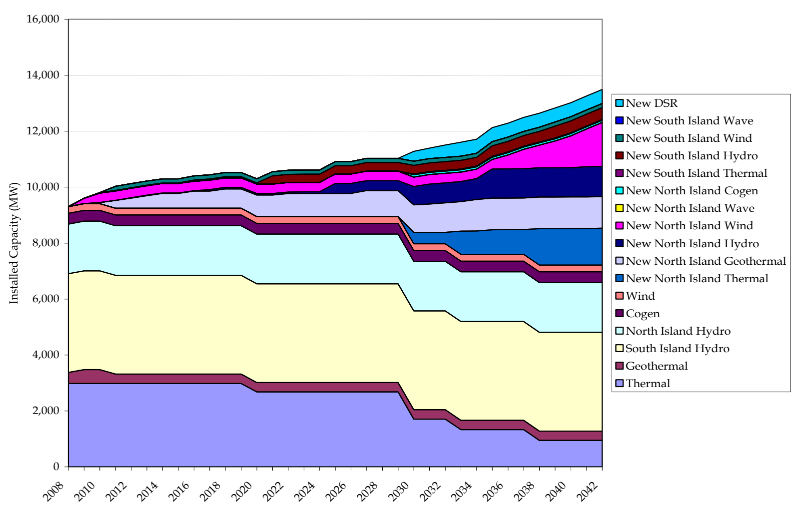
CEP: Case Study, continued



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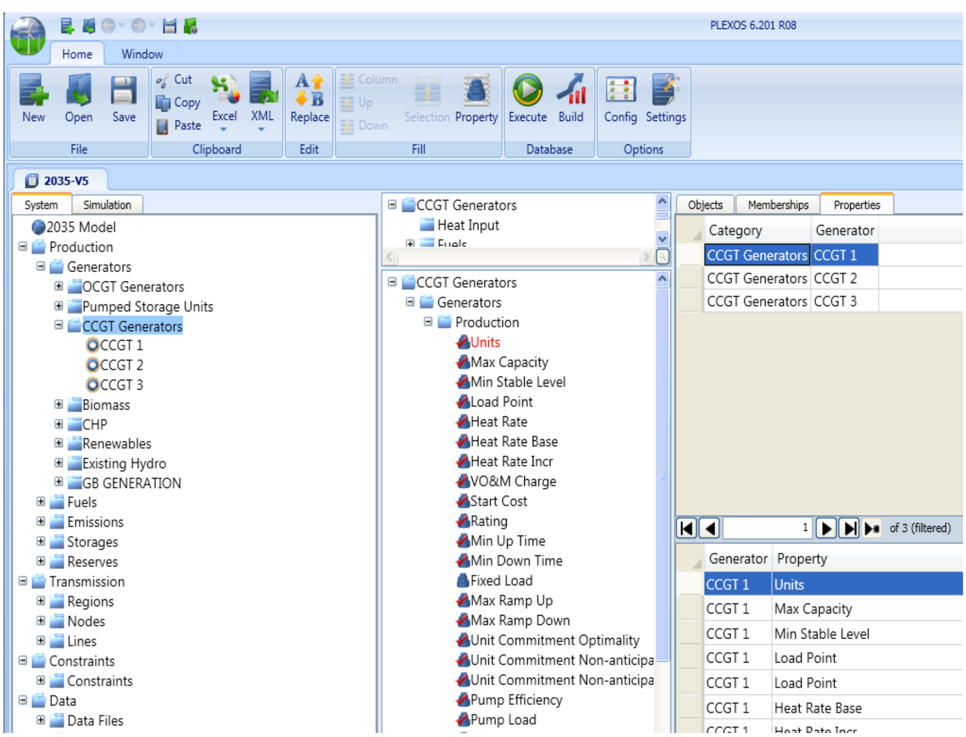
Operational Modelling

Operational Modelling

- Short timeframe (hours to days ahead)
- All market rules and known constraints modelled:
  - Transmission constraints
  - Ancillary services requirements (*i.e.* backup services), *etc*
- Key generation constraints and costs:
  - **Min Stable Level**: the minimum megawatt possible when unit is “on”
  - **Start Cost**: cost of getting a unit from “off” to MSL
  - **Fuel Cost**: cost of operating once “on”
  - **Min Up Time**: hours unit must stay up once committed
  - **Min Down Time**: hours unit must stay down after de-commitment
  - **Ramping**: maximum change in megawatt output
  - **Resource constraints**: fuel, hydro, wind
- ll objective is maximise welfare (minimise all costs incl. VoLL)

Operational Modelling, continued

- Unit commitment (on/off) decisions are integer *i.e.* you cannot turn on half a generator!
- Accepted solution methods:
  - Lagrangian relaxation (old method)
  - Mixed integer programming (new method)
- Recent advances in algorithm speed for mixed integer programming mean it is the preferred method
- Focus of analysis depends on user/market:
  - **IMO** interested in generation commitment/dispatch schedules and prices for energy and ancillary services
  - **Generator** wants to know best self-commitment schedule (for self-commitment markets where Generators decide on/off schedules)



Summary

Application	Detail Level (High, Mid, Low)	PLEXOS (algorithm, objective, method)
Capacity Expansion Planning	**Generation (M)** **Transmission (L/M)** **Load (M)**	**LT Plan** **Load driven, maximise benefit** **Deterministic or Stochastic MIP**
Transmission Modelling	Generation (M) Transmission (H) Load (H)	ST Schedule Load driven, maximise benefit Deterministic MIP
Market Analysis	Generation (M) Transmission (L/M) Load (M)	MT Schedule + ST Schedule Load driven, maximise benefit with non-marginal cost bidding Monte Carlo MIP
Operational Modelling	**Generation (H)** **Transmission (H)** **Load (H)**	**ST Schedule** **Load driven, maximise benefit** **Deterministic or Stochastic MIP**
Portfolio Optimisation	Generation (H) Transmission (L) Load (L)	ST Schedule Price driven, maximise profit Deterministic or Stochastic MIP

Thank you

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