Analysing the Impact of Wind Power

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Overview presentation

- Scope of the All-Island Grid Study work-stream 2(b)
- Methodology
- From model runs to conclusions

Scope of All-Island Grid Study work-stream 2(b)

- Impacts of renewable generation on All-Island power system:
  - Variability and predictability of renewable generation
  - Costs and benefits of absorbing various levels of renewable generation
  - Effects on emissions and costs of existing units
  - Most suitable mix of complementary conventional plants
  - Detailed model of system operation

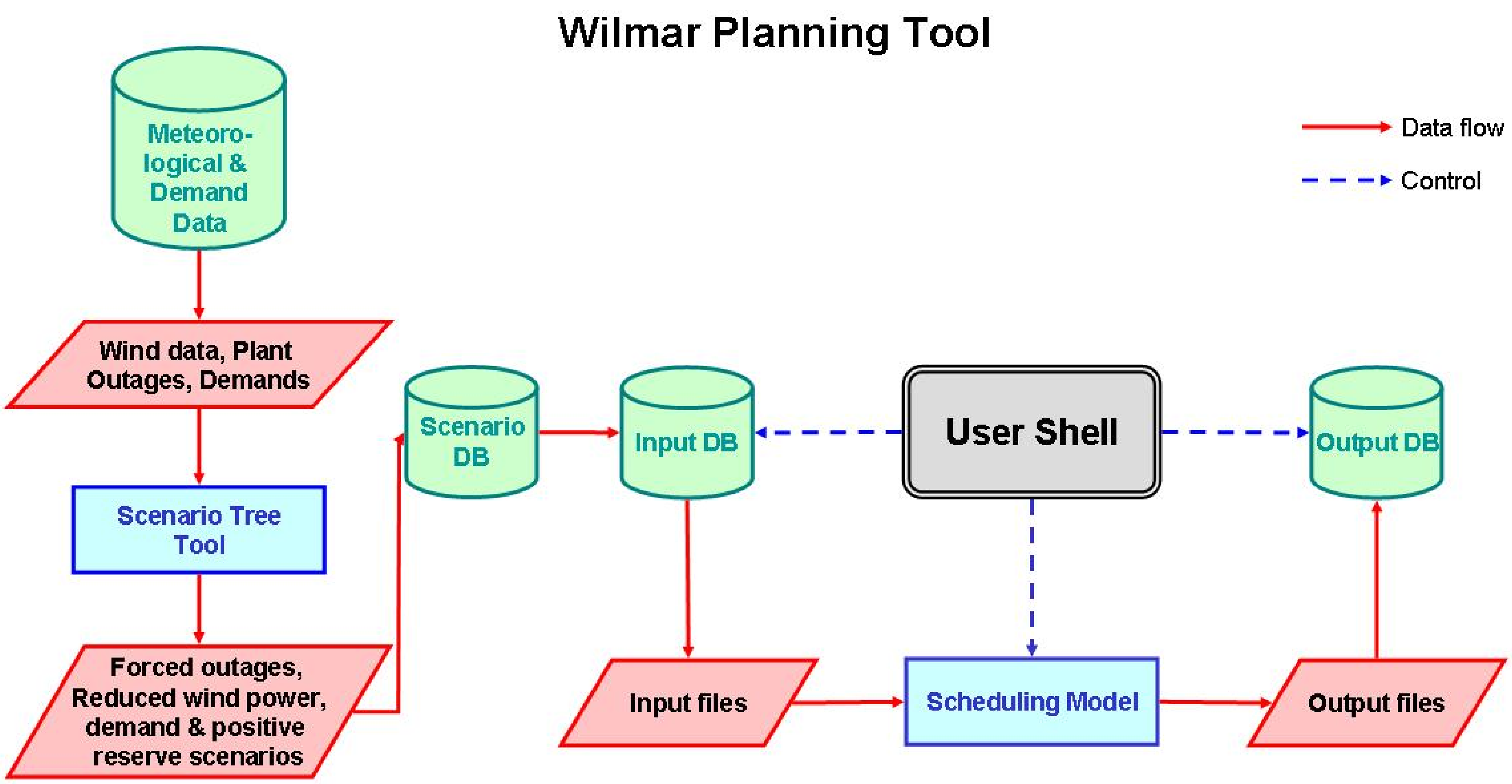
Methodology – Basic idea

- Improve decision making by using information contained in wind power production forecasts
- Information: Expected wind power production, but also precision of forecast, i.e. the distribution of the wind power production forecast errors
- Decisions before wind power is known: Day-ahead scheduling
- Decision after wind power is known : Down/up regulation of power plants

Methodology – Basic idea

- How:
  - Build system-wide stochastic optimisation model with the wind power production as a stochastic input parameter
  - Covering both day-ahead scheduling and rescheduling due to updated wind power forecasts
- Consequence: Model makes unit commitment and dispatch decisions being robust towards wind power production forecast errors

Model overview



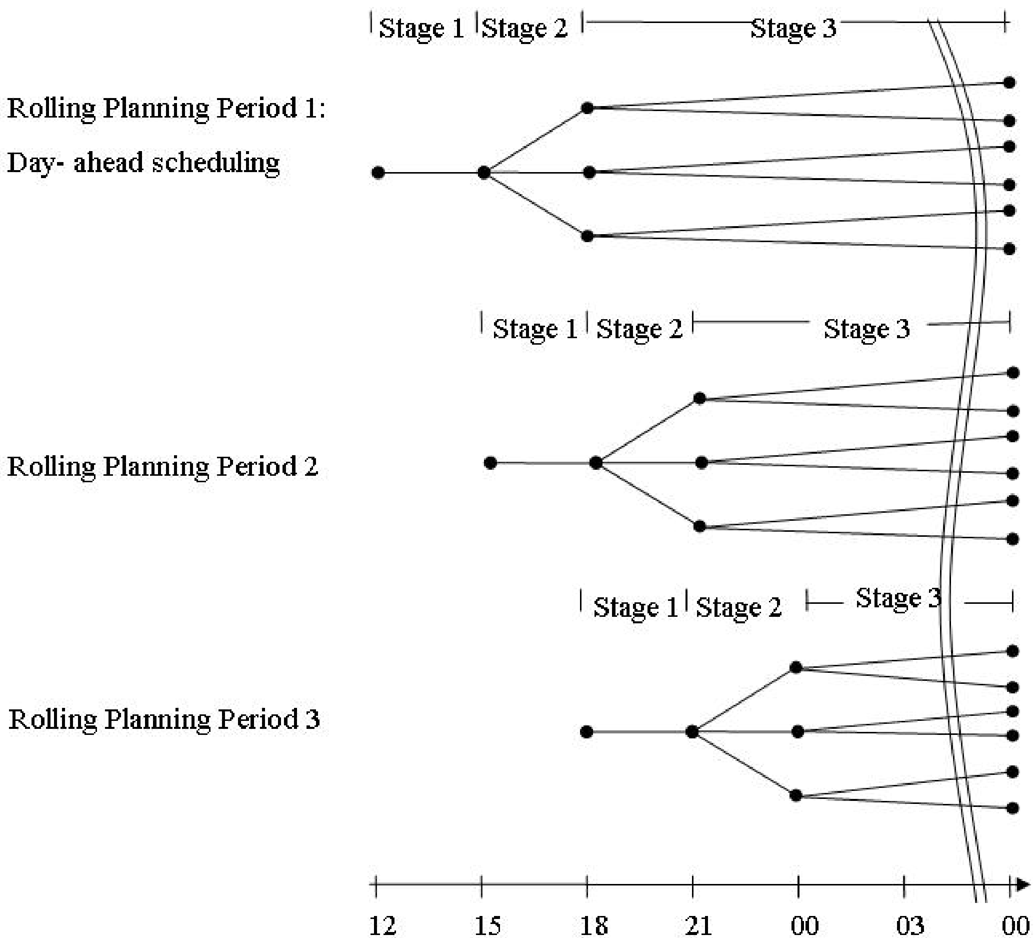
Functionality Scheduling Model (SM)

- Stochastic, mixed integer, linear optimisation model
- Stochastic input in the form of a scenario tree
- Stochastic input:
  - Wind power production forecasts (dispatch)
  - Electricity demand forecasts (dispatch)
  - Forecasts of demands for non-spinning positive reserves (unit commitment)
- Non-spinning positive reserve: demand for positive reserves that replaces spinning reserves (activation times above 5 minutes):
  - Demand time and scenario dependant (determined for forecast horizons from 5 minutes to 36 hours ahead)
  - Demand dependant on wind power and load forecasts
  - Both online and offline units can provide this type of reserve. Offline units must have start-up times lower than forecast horizon

Functionality Scheduling model

- First three hours in scenario tree deterministic:
  - Realised wind power production
  - Realised load
  - Demand non-spinning reserve (taking uncertainty in wind power production forecasts and load forecasts for forecast horizons 1 to 3 hours ahead into account)
- Optimisation over all outcomes represented by the scenario tree
- Minimisation of expected costs. Expectation taken over branches in scenario tree

Functionality Scheduling model



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Functionality Joint Market model

- Rolling planning:
  - 8 planning loops for each day-cycle (8 optimisation problems solved). Rolling planning moves three hours ahead in time for each new planning loop
- First planning loop:
  - Optimisation period covers 36 hours starting at 12 am (day one) and covering all hours in day 2
  - Forecasts horizons 4 to 36 hours ahead
  - Day-ahead dispatch decisions determined
  - Realised unit commitment and dispatch for the first three hours in the planning loop (happening after realisation of stochastic parameters)
  - Unit commitment and dispatch plans made covering each scenario for the outcome of wind power, load and demand for non-spinning positive reserve

Functionality Joint Market model

- Planning loop 2 to 8:
  - Optimisation period always ends at 12 pm day 2 $\Rightarrow$ optimisation period is reduced with 3 hours in each planning loop
  - Taking day-ahead scheduling into account
  - Rescheduling of unit commitment and dispatch decisions due to updated forecasts (new scenario tree in each planning loop, forecast horizons reduced with three hours)
  - Realised unit commitment and dispatch for the first three hours in each planning loop (happening after realisation of stochastic parameters)
- Planning loop 9:
  - A new day-cycle start now covering from 12 am (day two) to 12 pm day 3

Functionality Joint Market model

- Output from JMM:
  - In general: levels of each variable and marginals (shadow prices) of each equation.
  - Realised hourly unit commitment and dispatch of each unit
  - Realised distribution of each reserve power category on units
  - Hourly power exchange with Great Britain
  - Hourly emissions of CO_2, NO_X and SO_2 from each unit
  - Total system-wide operational costs: fuel, start-up (and shut-down), variable operation and maintenance, costs connected with consuming CO_2 emission permits, loss in transmission line

Scenario Tree Tool

- Generates scenario trees for
  - wind power production forecasts
  - electricity demand forecasts
  - demand for non-spinning positive reserve
- Generate time series for forced outages of power plants
- Estimate LOLP of a given generation portfolio
- On the basis of:
  - Historical hourly time series of wind power production (or wind speed) and electricity demand
  - Assumptions about wind production forecast accuracies and load forecast accuracies for different forecast horizons
  - Data for outages and the mean time to repair of power plants
  - Future year scenarios of installed wind power capacity and yearly electricity demands
  - Risk level assumption when determining need for non-spinning positive reserve

Model runs

- Year 2020:
  - Starting point:
    - Five generation portfolios taken from All-Island Grid Study work-stream 2(a)
    - Generation portfolios represent “optimal portfolios” for a given combination of fuel prices, CO_2 emission permit price and wind turbine costs
  - Additional model runs possible e.g.:
    - To test improved generation portfolios compared to those from 2(a)
    - Impact of reduced forecasting errors of wind
    - Impact of unit constraints

From model runs to output of study

- How different penetration levels of renewable generation affects system-wide costs and emissions : compare cases
- Amount of required reserve over different forecasting horizons: Need for non-spinning positive reserve
- Distribution of required reserve on power plants especially on spinning and off-line power plants : Scheduling model
- How does the relative mix of base-load and peaking plant in generation portfolios affect system-wide reserve management, emissions and costs: compare cases

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From model runs to output of study

- Impact of unit constraints on variability management: compare model runs with different values of unit constraints
- Impact of improved forecasting: compare with deterministic model run
- Effect of extraneous variables (fuel price, CO2 price): compare cases
- Effect of energy storage: set up case with extra energy storage
- Reliability of All-Island system: Scenario Tree Tool calculates LOLP, Scheduling model indicates when system has problems

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