ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA – ICAI
Instituto de Investigación Tecnológica

Stochastic Unit Commitment Considering Uncertain Wind Production: Application to an isolated system

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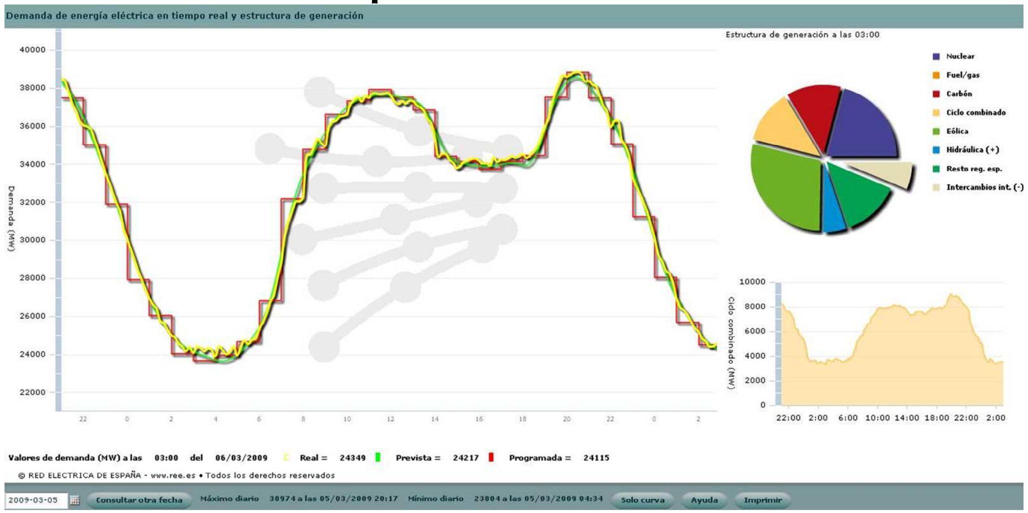
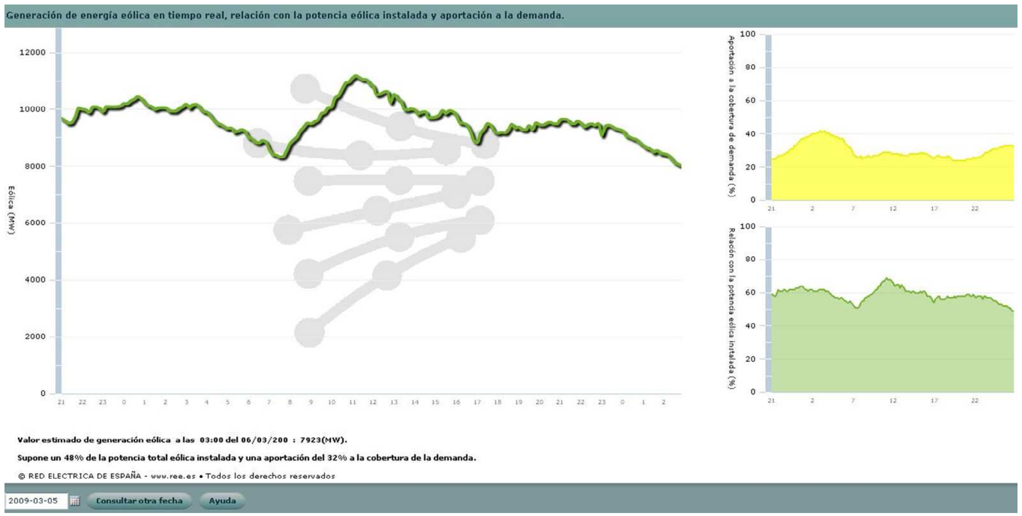
Situation of wind production in Spain

- Mainland Spain:
  - Year 2008: 11.8 % wind energy, 15.576 MW (17 %) installed on Dec-19-2008
  - Forecasts and goal: 20000 MW in 2010 and 30000 MW in 2020, 20 % wind energy in 2020
    - Activation of "Plan de Acción E4 2008-2011" and others
- Canary Islands:
  - There are plans to substantially increment wind power generation

Situation of wind production in Spain

- 05.03.2009: Instantaneous peak 11.203 MW at 11:09 h (29.5 % of demand).





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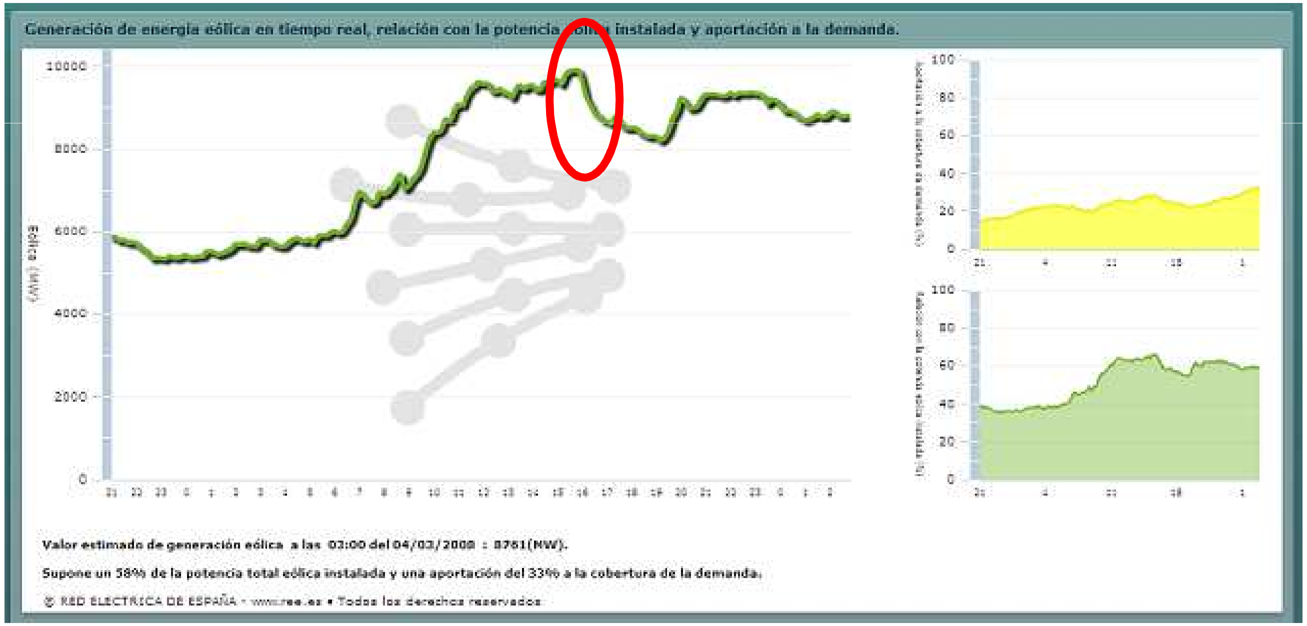
Situation of wind production in Spain

- Wind power generation curtailment (Mar-4 2008)
- Instantaneous peak 10032 MW at 15:53 h (28 % of demand). Hourly peak 9803 MW between 15:00 and 16:00 h
- A reduction order of wind generation was sent



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Problem Description

- Unit Commitment:
  - Planification of short-term generation
  - To know which generation units are turned on and shut-down in each hours taking into account cost-minimization under certain restrictions:
    - Demand must be balanced
    - Maintain system security (Reserves)
    - Other restrictions (regulatory, tecnical)
    - Weekly or daily approach
- Why?
  - Economic losses
  - Mathematical interesting particularities (non convex, entire variables, big size)

Problem Description

- Effects of intermittent generation:
  - In power
    - Balancing mechanisms, operating reserves.
      - Rapid short term adjustments needed to manage fluctuations over short periods of time (minutes to hours).
    - Reliability impact
      - Will there be enough generation to meet peak loads? Determine some adequacy reliability measures of the system. No dynamic or very short term effects.
      - Capacity credit is the contribution of intermittent generation to reliability (20-30 % are common numbers for wind power). Effective Load Carrying Capability (ELCC) measures this capacity credit.
  - In energy
    - A whole week with no wind generation

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Model Approach

- Objectives:
  - Analyze the impact of integrating a large-scale of intermittent generation (IG) in the medium and long term operation of Spanish electric system (2030 horizon)
  - Identify and evaluate possible operation actions or regulatory measures to allow increasing the amount of IG without compromising the security of supply
  - Estimate the maximum amount of IG incorporated into the system for a certain security criterion
- Application in case study to small isolated system with large wind generation (no solar/hydro considered)

Model Approach

- Hypothesis:
  - Transmission/distribution network does not affect
  - Load flow profiles are going to change but they can be managed by current transmission network
- Time scope for case study:
  - 1 day

Modeling Approach

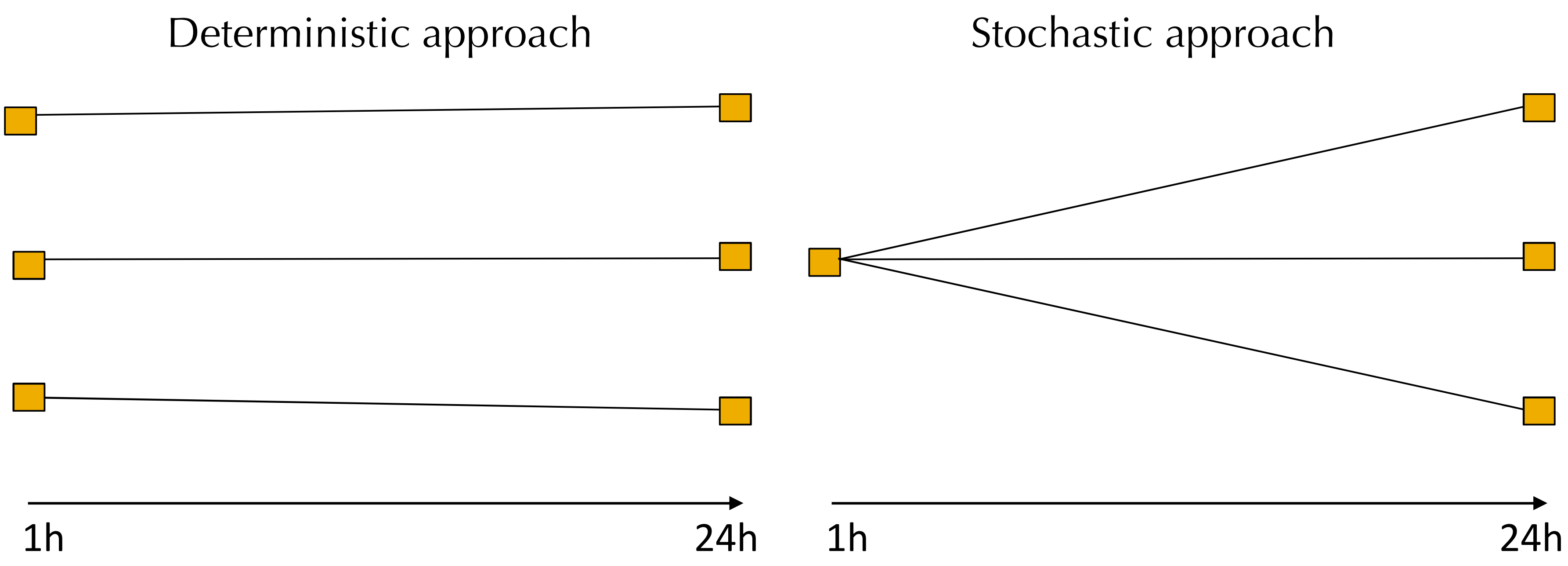
- Input Data:
  - Demand + Spinning reserve upwards/downwards per hour:
    - Balancing reserves depend on each scenario and hour
      - Up: Wind power forecasting error + % of peak load + largest thermal unit
      - Down: Wind power forecasting error + % of peak load
  - Generation capacities (min/max)/ Up and down ramp rates
    - Technical characteristics of generation plants
      - Ramps up/down
    - Costs of generation plants
      - Fixed and variable heat rates and fuel price
      - Emission rate and CO_2 price
      - Start-up costs

Modeling Approach

- Input Data II:
  - Wind: Penetration level given by indicative expansion plans (for example, 30 % in 2030)
    - Output forecasting at 14 h for every day to be used by the daily unit commitment
    - Prediction errors of previous forecasting in three scenarios
    - Extrapolation of current available data
      - New capacity inv.+ Future off-shore wind power generation
  - New ways for electricity consumption, storage and generation
    - Plug-in hybrid cars / Energy stored as hydrogen
  - Potential use of active demand management actions
    - Generalized use of load shedding contracts
    - Hourly meters and price responsive demand
    - Innovative electricity tariffs

Modeling Approach

- Wind:
  - Three different wind prediction errors considered
    - 1st stage decision: Unit Commitment
    - 2nd-stage decision: Production, Non-served Energy



Modeling Approach

- Stochastic Unit Commitment
  - Cost Minimization

    s.t.
    - Demand balance
    - Reserve up/down
    - Generation limits min/max
    - Ramping constraints up/down
    - Unit Commitment: logic coherence for start-up & shutdown ties

- Output Data:
  - Hourly plan with start-up and shut-down decisions for each generation unit
  - Generation of each thermal unit
  - Non served Energy
  - Total Cost

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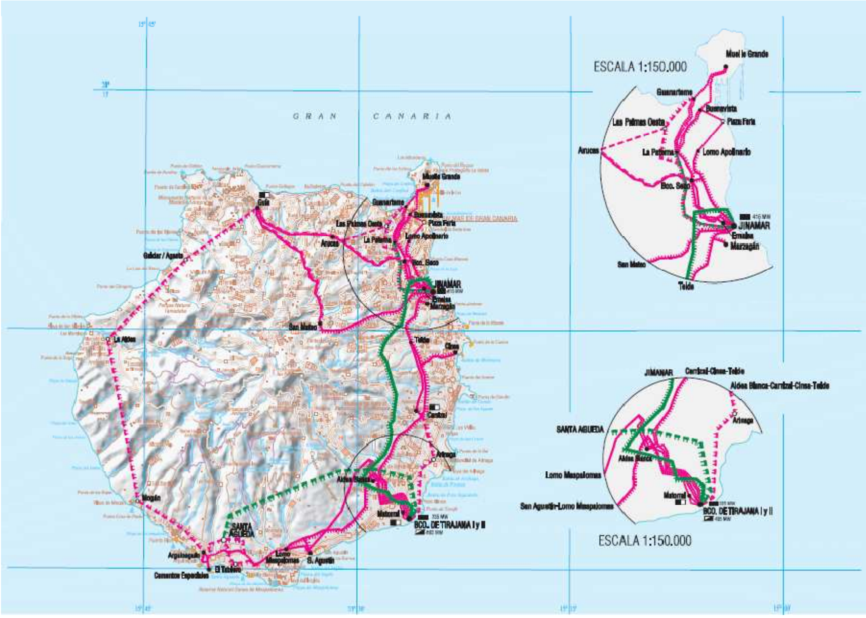
Case Study: Gran Canaria

- Gran Canaria:
  - small island in Spanish territory
  - chosen as it has to cope with demand coverage on its own
  - no interconections



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- Generation units
  - 20 thermal units (CCGT,Gas Turbines,Fueloil,Gasoil)
  - Installed capacity: ~930 MW
  - No hydro plants

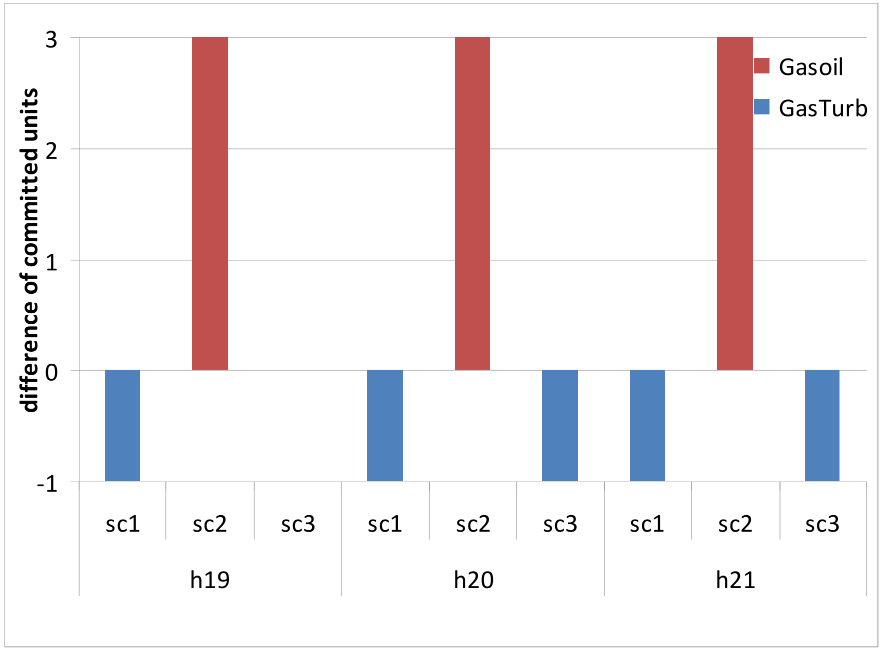
Case Study: Gran Canaria

- Data:
  - Generation data
    - Variable, fixed and start-up cost regulated und published in BOE (2006)
  - Wind data
    - Historic time series of wind production and error of wind forecast for Spain
    - Scaled to Gran Canaria
  - Demand data
    - Historic time series for Spain
    - Scaled down to Gran Canaria
    - Reserve 3%

BOE (2006): Boletín Oficial de Estado, BOE núm. 77, 31 of march 2006, pp. 12484-12556

Case Study: Gran Canaria

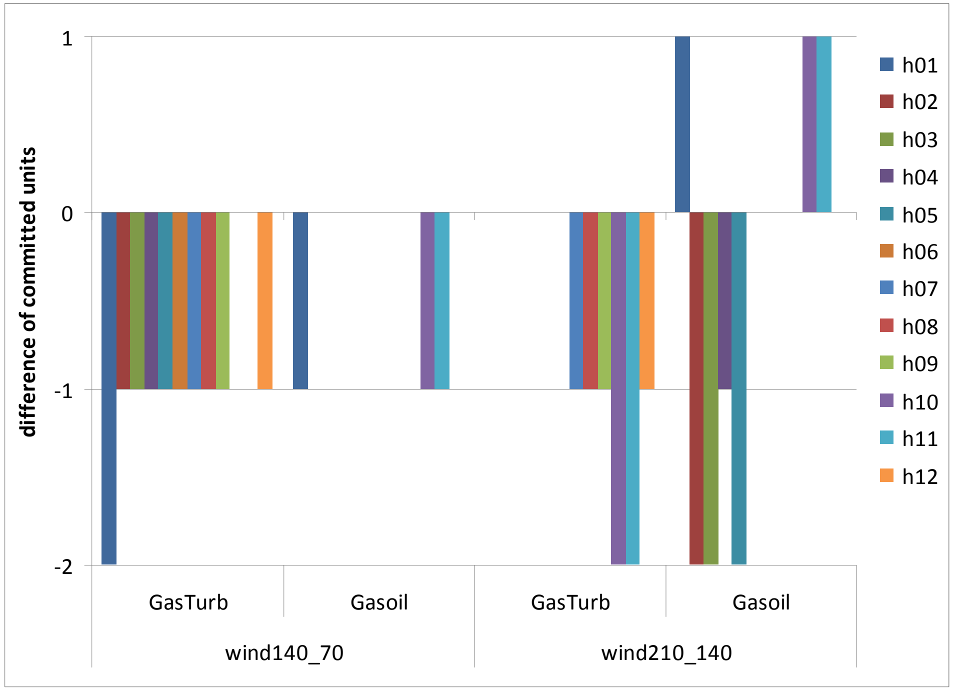
- Comparison of stochastic and deterministic approach:



- Differences between stochastic and deterministic approach mainly in peak hours (peaking units gasoil and gas turbines)
- Stochastic approach taking into account all wind scenarios at once prefers gasoil plants instead of shutting them down and use gas turbines in low wind scenarios
- EVPI: ~ 34.000 € in one day → that is a cost advantage of 3%

Case Study: Gran Canaria

- Comparison of medium to low and high to medium installed wind capacity:
  - Low = 70 MW
  - Medium = 140 MW
  - High = 210 MW



- Comparison: 140 MW to 70 MW → saving of conventional production (mostly gas turbines and in some hours gasoil units)
- Comparison: 210 MW to 140 MW → saving of conventional production in the case of gas turbines, but some gasoil units running on minimum to not shut-down plants (due to reserve)

Conclusions

- Advantages of stochastic over deterministic optimization
  - Adequate treatment of wind characteristics
- Higher wind generation does save conventional energy (not capacity) only up to certain point
  - Problems might appear due to system stability (reserves)

- Currently working on:
  - Electric cars
- Further Research Work:
  - Demand Management
  - Further storage facilities
  - …

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