Modelling wind availability with SPINES - scenario generation (and implementation)

ETSAP WS
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Pernille Seljom & Asgeir Tomasgard (NTNU)

Motivation

- Is TIMES a suitable tool with increased share of wind and PV?
- Optimal investments in flexibility?
- Is exogenous peak contribution of wind and PV sufficient?
- In dispatch models, a stochastic mod. of wind and PV is state-of the art
  - Why don't we use the same approach?

Outline

- Stochastic Programming and SPINES
- Case study Denmark
  - Wind characteristics
  - Scenario generation
  - (Implementation)
- Concluding remarks

What is Stochastic programming (SP) ?

- A framework to model uncertainty and to value flexibility
  - Decision making under uncertainty
- In “real life” we make decisions in the light of an uncertain future (stochastic)
- In TIMES the future is often given (deterministic) both on a short-term and long-term

Further description:

Birge, J.R., Louveaux, F., 1997. Introduction to Stochastic Programming

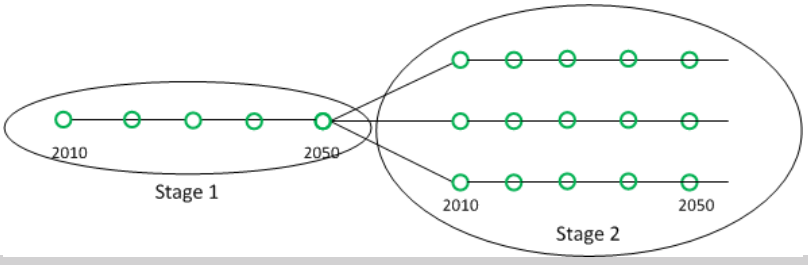
What is SPINES ?

- SPINES
  - Stochastic representation of short-term uncertainty
  - Short-term uncertainty = Operational uncertainty
- Objective function
  - Investment cost + expected operational costs
  - Possible future realisations represented in a scenario tree
- SP traditionally used to model long-term uncertainties in TIMES
  - Example future climate policies
- Further description:

  Loulou, R., Lehtila, A., 2012. Stochastic Programming and Tradeoff Analysis in TIMES, TIMES Version 3.3 User Note p. 46.

Example: 2-stage model

- Model horizon: 2010 to 2050
- Stage = New information is revealed
- Two stage model
  - 1st stage = investment decisions (2010 – 2050)
  - 2nd stage =operational decisions (2010 – 2050)
    - Operational decisions for all possible realisation of the uncertain parameter/ SOW



Wind availability with SPINES

Why…

- Increased share of wind and PV in the energy production mix
  - Higher requirements of flexibility in the energy system
- Endogenous peak contribution of wind and PV
  - Depend on energy system characteristics; transmission capacity, storage capacity, share of intermittency + +
- Why not…
  - Increased computational complexity
  - Require scenario generation/ a representation of possible future realisations

Case study - Denmark

- Regions
  - Denmark West (DK-W alias DK-1)
  - Denmark East (DK-E alias DK-2)
- Time resolution
  - Model period: 2010 to 2050
  - Annual time slices = 4 x 12 = 48
    - 4 seasons
    - 12 daily periods
- End use sectors
  - Agriculture, Transport, Industry, Commercial and Residential

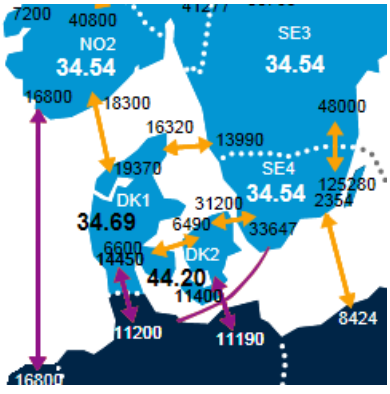


Figure: Nord Pool Spot 20.11.2012
Area prices and capacities

Denmark – scenario generation

- Scenario generation – Representation of possible future realisations
- Hourly wind production data from 2000 – 2011
  - Production per installed capacity (0-1)
  - Scaled to fit a given annual capacity factor
- Criteria for scenario generation
  - Capture correlation
  - Give a good representation of the true distribution
  - Stability

Wind power characteristics

- Expected production (% capacity)
- Monthly and diurnal variations

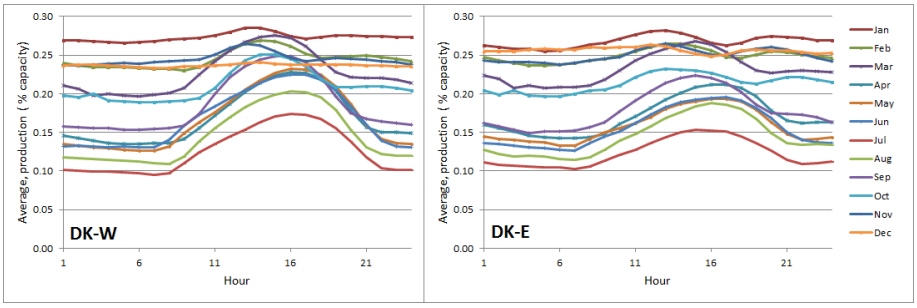


Figure: Annual capacity factor: 20 %

Wind power characteristics

- Variance of production (% capacity)
- Monthly and diurnal variations

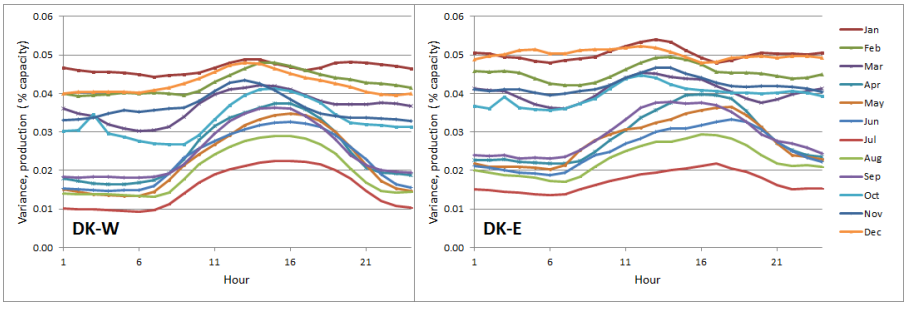
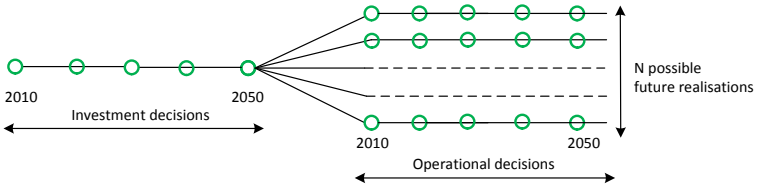


Figure: Annual capacity factor: 20 %

Scenario generation

- Uncertain parameter:
  - Availability of wind power, relative of installed capacity (0 – 1)
- Two-stage model
  - A two-stage model is a relaxation: No uncertainty related to operation of storage units
  - N scenario = N possible future realisations



Scenario generation

- Methodology: For N scenarios, select the scenarios that give a *good match* of first four moments of the true distribution
- Correlation
  - Hourly correlation: Select 24 chronological hourly wind production data (model input = every 2nd hour)
  - Regional correlation: Use same sample for both regions
  - Assume no seasonal correlation

Scenario generation

Season	N scenario
Month	N/3 scenario

Example: 30 scenario, 10 scenario in June

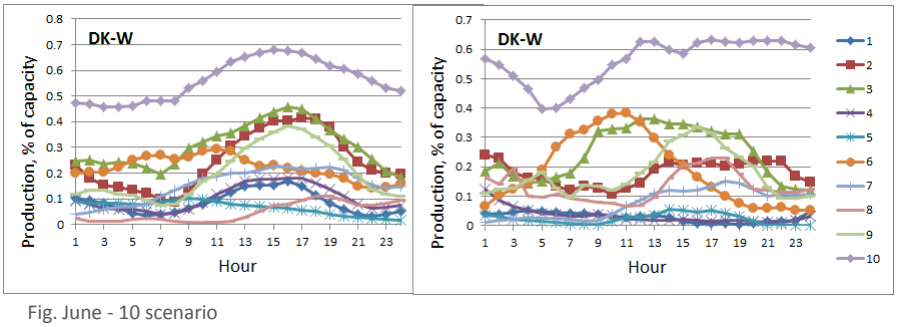


Fig. June - 10 scenario

Scenario generation

- 10 scenario in June – All 4 moments deviate significant from the true distribution
- How many scenarios is needed?

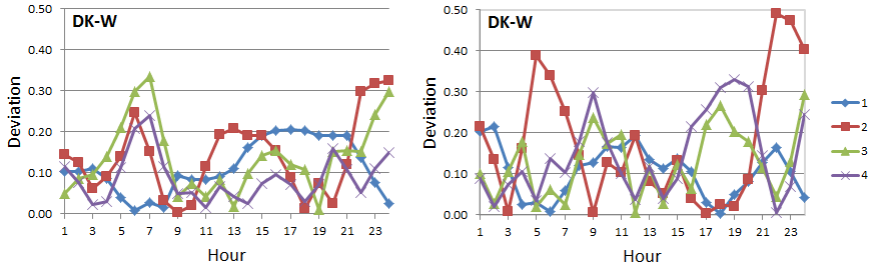
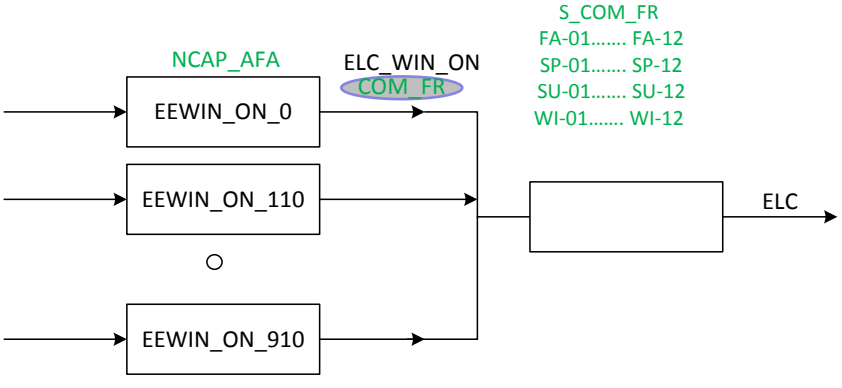


Fig. June - 10 scenario- Dev. 4 moments

Modelling wind power



Implementation

- SPINES is implemented to a preliminary version of the Danish TIMES model
- Example 5 scenarios
  - Average: Wind peak contribution = 20 %

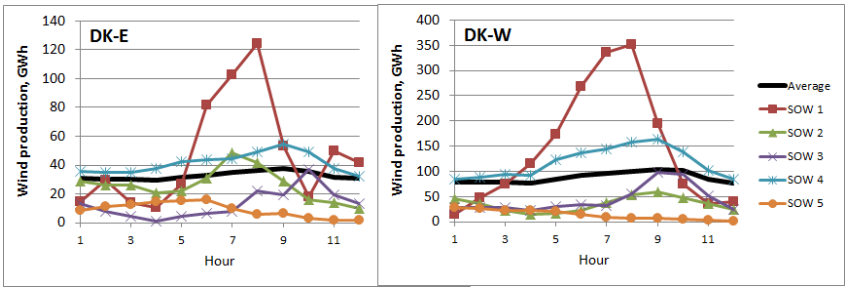
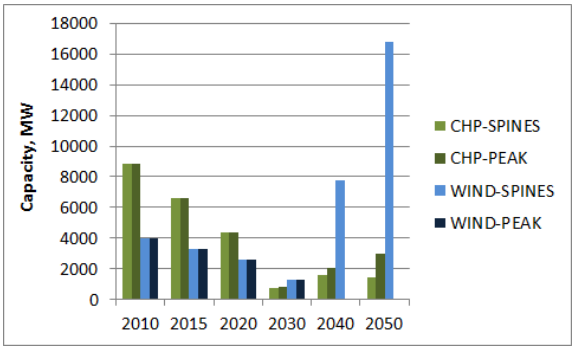


Fig. Wind production in Summer 2015

Implementation

- Example: Result of 5 scenario SPINES
  - No growth constraint
  - Preliminary model, not complete!!!



→ SPINES gives different model results! WHY!

Concluding remarks 1

- SPINES makes short-term uncertainty a part of the investment decision
- The future energy system require more flexibility, SPINES make it possible to value the flexibility.
- Scenario generation is a key challenge with SPINES
  - Methodology
  - Number of scenario
- Using SPINES in TIMES is straight forward (almost)
  - $SET SPINES 'YES'
- A two-stage approach gives = manageable model size

Concluding remarks 2

Further work:

1. Test different scenario tree in model
   - How many scenario is needed?
   - What is a good scenario generation method?

2. Is SPINES worth the effort?
   - Value of Stochastic Solution/ "Cost of ignoring uncertainty"
   - How do the results differ for various scenarios
     - Value of wind and PV
     - Value of storage and flexibility

Thank you for the attention!

pernille@ife.no