Aalto-yliopisto
Perustieteiden
korkeakoulu

Portfolio optimization of reliability measures for wind turbines (topic presentation)

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Wind energy and wind turbines

- Wind energy is the fastest-growing energy source along with solar energy.
- Wind turbines are not manned, as opposed to many other power plants.
  - ↳ Corrective maintenance may take long! Therefore preventive maintenances (reliability measures) are important.
    - ↳ In particular offshore wind turbines are difficult to access.
- Optimizing the combination (portfolio) of reliability measures increases the reliability and thus the utility of a wind turbine.
  - ↳ Even a small improvement to the utility of a single wind turbine may lead to a large impact, when considering a whole wind farm.

Key world energy statistics. 2017, IEA.

Reliability modelling

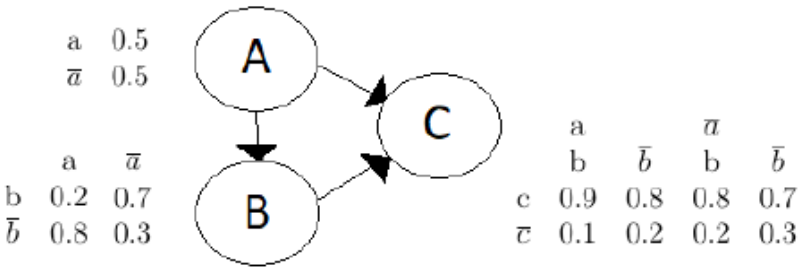
- The failure events of the wind turbine are mapped into a Bayesian Network (BN).
- A BN is a directed acyclic graph composed of nodes and directed arcs.

  ↳ **Nodes** represent wind turbine components and internal/external factors.

  - Two or more states. - Different combinations of states lead to the failure of the wind turbine or a weakened power production.

  ↳ **Directed arcs** represent conditional dependencies between nodes

  - e.g. the node C is conditionally dependant on the nodes A and B.



An example BN

Reliability modelling

- Reliability measures impact the failure probability of the components, thus they reduce the risk that the wind turbine is not operating correctly.

- Bayesian networks are widely applied in many fields, such as medicine, computer science and risk analysis.
- Reasons why BNs are widely used:
  - ↳ Easy to build and express probabilistic systems
  - ↳ Consistent with probability theory
  - ↳ Can handle imprecise or qualitative information

Objectives

- Learn about Bayesian Networks and utility theory.
- Model the reliability of a wind turbine as a BN.

  ↳ Mapping failure dynamics as a probabilistic graphical model.
- Analysis of reliability measures for wind turbine components.
- Support the selection of cost-efficient portfolios of reliability measures (portfolio optimization).

Methods

1. Risk assessment
   - ↳ Bayesian Network to evaluate the risk based on failure likelihood and impact on electricity production.

2. Portfolio optimization
   - ↳ Objective function: Electricity production
   - ↳ Decisions: Different portfolios of reliability measures
   - ↳ Constraints: Budget, technical (safety, synergies)

Sources and data

- System analysis and failure dynamics
  - ↳ US patent for direct drive wind turbines

Bywaters, Garrett, et al. "Direct drive wind turbine." U.S. Patent No. 7,183,665. 27 Feb. 2007

- Failure probabilities
  - ↳ Swedish study on wind turbines

Ribrant, J., \& Bertling, L. (2007, June). Survey of failures in wind power systems with focus on Swedish wind power plants during 1997-2005. In Power Engineering Society General Meeting, 2007. IEEE (pp. 1-8). IEEE

- Wind conditions
  - ↳ Finnish meteorological institute
    - ↳ Harmaja island (Helsinki)

Tools/Software

- GeNIe
  - ↳ BN model
    - ↳ Modelling failure dynamics
    - ↳ Applying reliability measures to system components
    - ↳ Computing the utility of electricity production
- MATLAB
  - ↳ Optimization model
    - ↳ Coding the portfolio optimization
  - ↳ Performing sensitivity analysis on results

Schedule

- April/18: Literature review, BN model
- May/18: First draft, optimization model
- 11th of June/18: Topic presentation
- June/18: Analysis of the results, finalising the thesis
- September: Presentation of the thesis