Aalto-yliopisto
Perustieteiden korkeakoulu

Portfolio optimisation of reliability measures for wind turbines (Final presentation)

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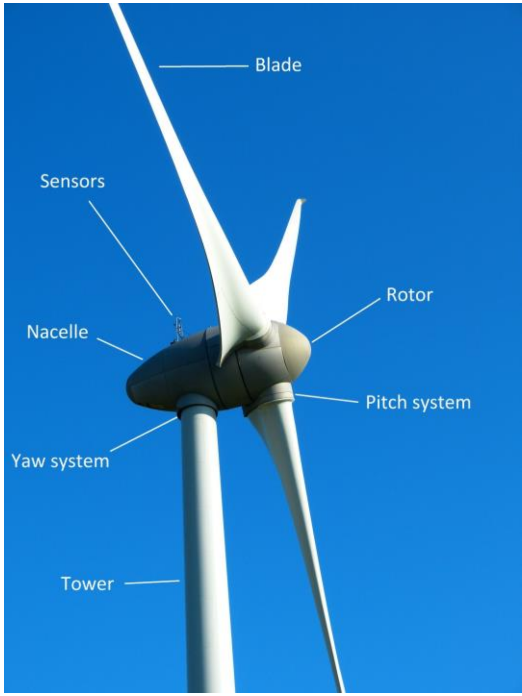
Background

- Reliability engineering
  - Loss elimination, risk management and asset lifecycle management
  - Mostly preventing or reducing the likelihood of failures
- Bayesian networks
  - Probabilistic graphical models
- Portfolio optimisation

Objectives

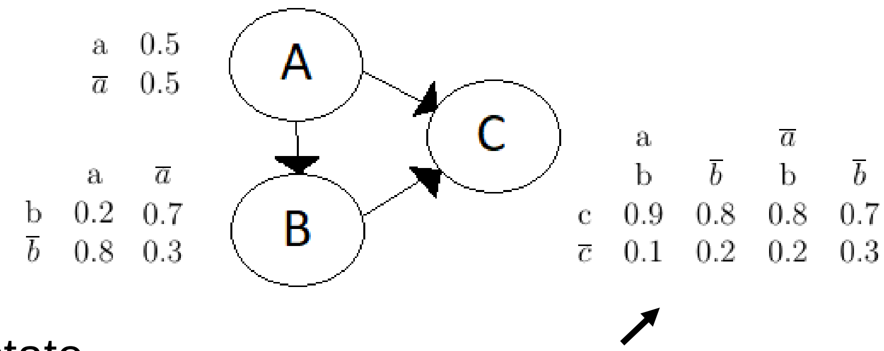
1. Build a reliability model for a wind turbine
   - Based on components and their failure probabilities
2. Determine the significance of components
   - On utility and safety
3. Optimise reliability measures
   - Finding optimal portfolios



Methods

- Bayesian networks
  - Nodes: Random variables (components) with discrete states
  - Edges: Dependencies between variables

- Sensitivity analysis
  1. Change probability of a state
  2. Calculate the effect for an other state



Conditional probability table (CPT)

Methods

- Portfolio optimisation

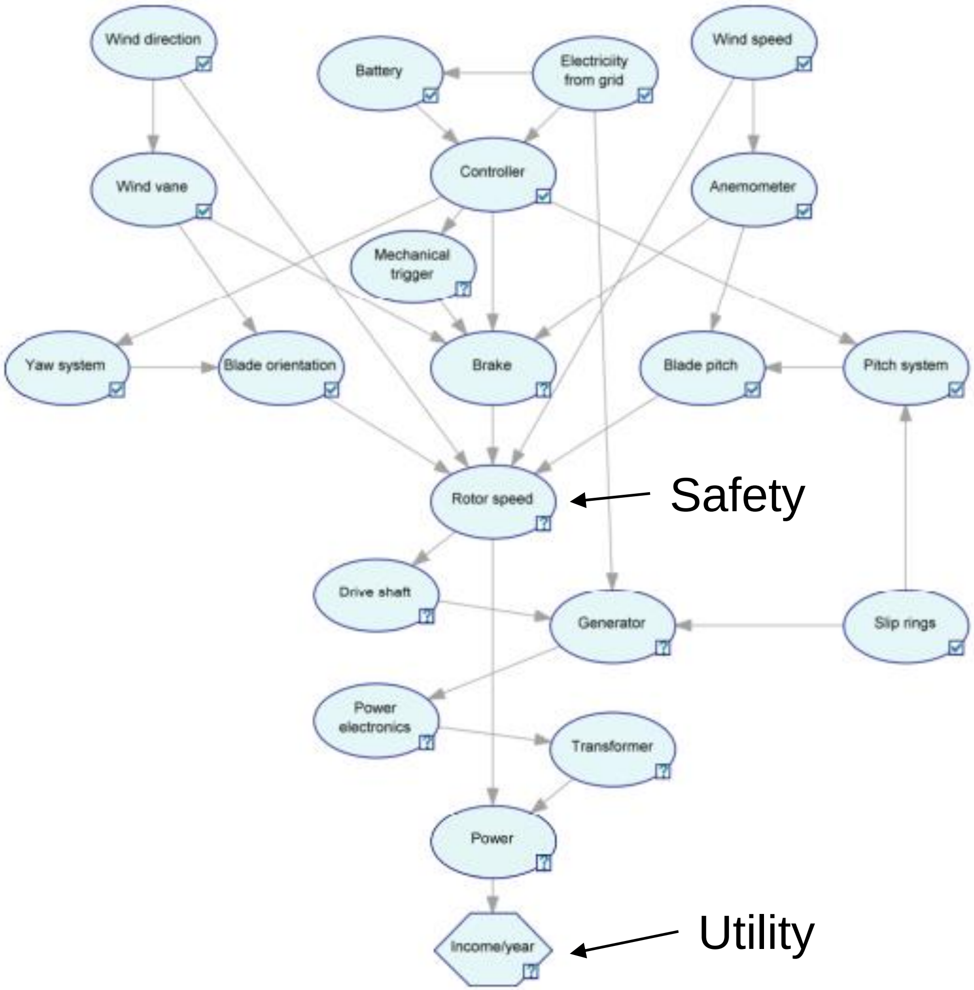
  - Portfolio of decisions (reliability measures) with costs to optimise

  - Objective:
    - Maximise the reliability/expected utility of the wind turbine

  - Constraints:
    - Budget, safety of the system

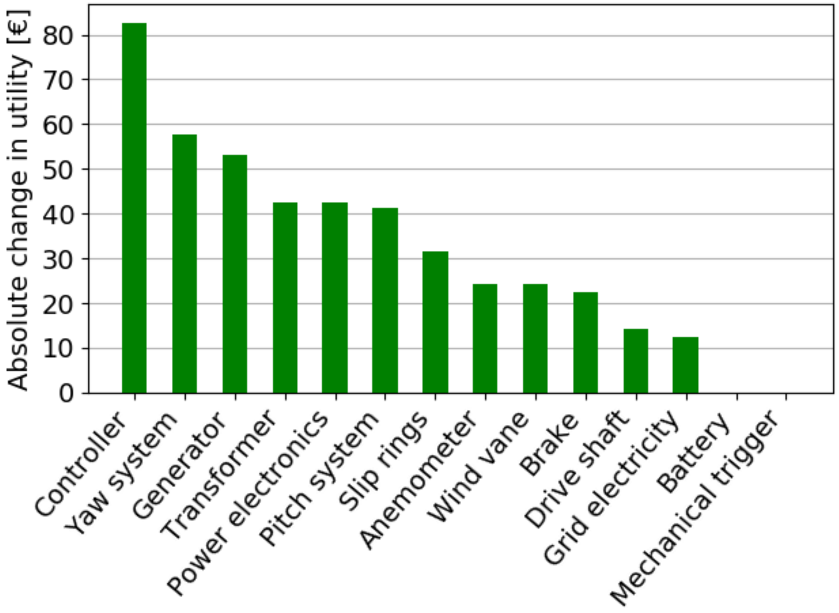
Reliability model

- Components of a wind turbine and their dependencies ->
- Each component has a set of states
  - Probabilities defined by conditional probability tables
- Utility associated with top node
- Safety associated with rotor speed



Results

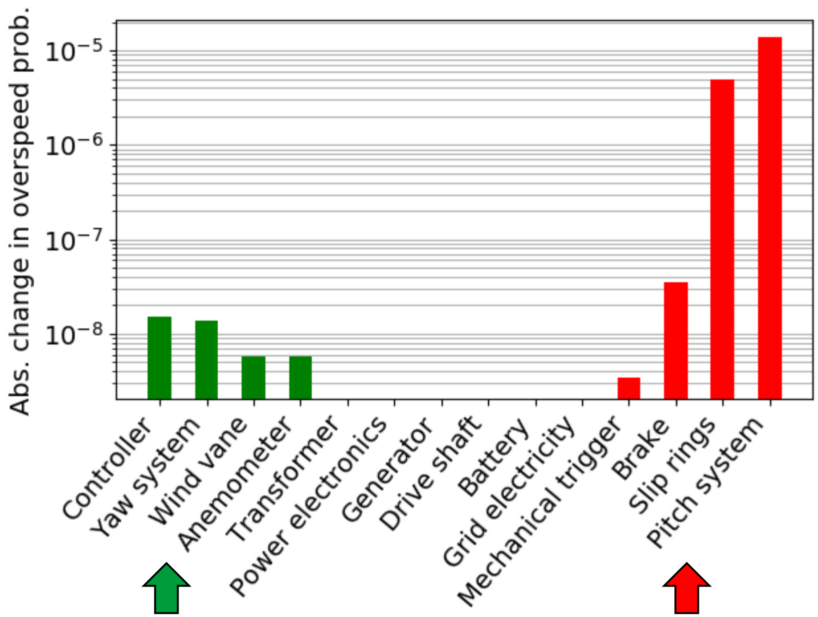
Impact of 10% decrease in failure probability of components on the expected utility



- High correlation with component reliability
- Effects very small due to reliable components

Results

Impact of 10% decrease in failure probability of components on overspeed probability:

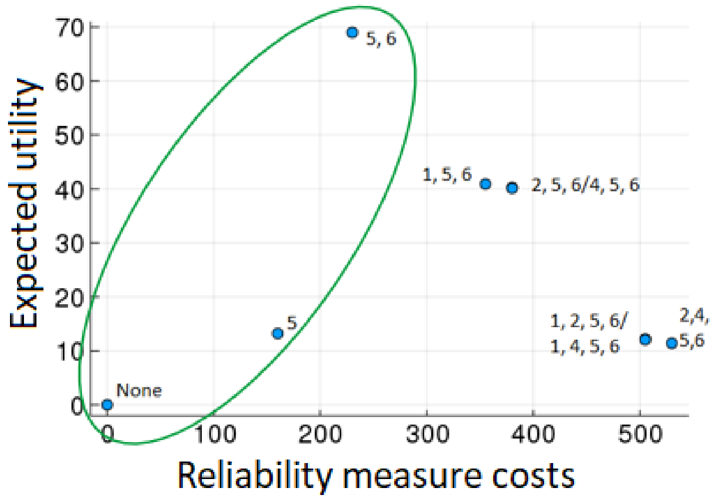


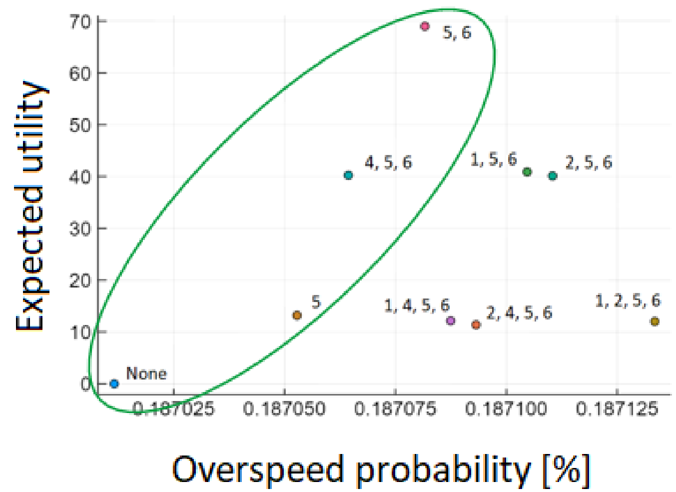
- Increase in operational time -> Higher chance for high wind speeds + failure

- Pitch system prevents overspeed first if slip rings operational
- Then brake via controller or trigger

Results

Non-negative utility portfolios:





Target node	Index	Reliability measure	Reduction	Cost [€]
Wind vane	1	Minor repairs	40%	125
Anemometer	2	Minor repairs	50%	150
Controller	3	Monitoring system	40%	400
Mechanical trigger	4	Testing the system	50%	150
Yaw system	5	Hydraulic fluid change	30%	80
	6	Gear lubrication	30%	120
Slip rings	7	Replacement	40%	300
Brake	8	Brake disc change	20%	300
	9	Brake pads change	30%	200
Generator	10	Electric coils repairing	25%	500
Transformer	11	Cooling improvements	30%	400

Summary

(Responsible for the orientation of the system)

- Wind turbine components very reliable
  -> Effect of reliability measures small
- Reliability of the controller and yaw system have the largest impact on the expected utility
- Reliability of the pitch system has the largest impact on overspeed probability

(Responsible for the angle of the blades)

- Instead of short term (yearly) utility maximisation; loss prevention, safety engineering and asset lifecycle management may provide larger benefits

Sources

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