Research on Infrastructure Asset Management – with power system applications

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Asset Management - Concepts

- Asset management (AM) is a concept used for planning and operation of the electrical power system
- The ***aim*** of AM is to handle physical assets in optimal way in order to fulfil an organisations goal whilst considering risk where:
  - the goal could be maximum asset value, maximum benefit or minimal life cycle cost
  - the risk could be defined by the *probability of failure occurrence and it consequence* e.g. unavailability in power supply to customers

Asset Management - RCM

- Reliability-Centered Maintenance is a systematic risk based qualitative method that aims to optimize maintenance achievements

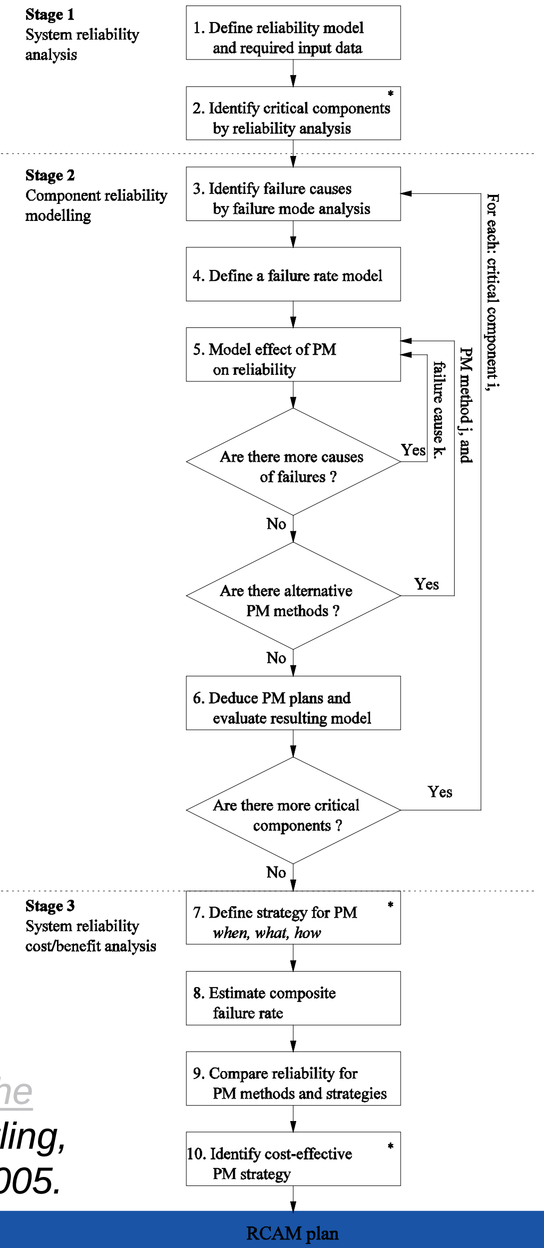
- The following features define and characterize RCM:
  1. preservation of system function,
  2. identification of failure modes,
  3. prioritizing of function needs, and
  4. selection of applicable and effective maintenance tasks.

Asset Management - RCAM

- RCM does not solve the fundamental problem of how the system reliability is impacted by component maintenance
- With the aim to solve this problem a quantitative method for RCM has been developed at KTH i.e.
    - Reliability-Centered Asset Management
- RCAM includes a relationship between reliability performance indices and the effect of maintenance measures, outgoing from causes of failures and failure mechanism for components in the Electric Power System $\lambda(t,PM)$

Asset Management - RCAM

- Stage 1: System reliability assessment identify critical components.
- Stage 2: component reliability modeling and the effect of maintenance λ(t,PM).
- Stage 3: System reliability assessment and cost analysis.



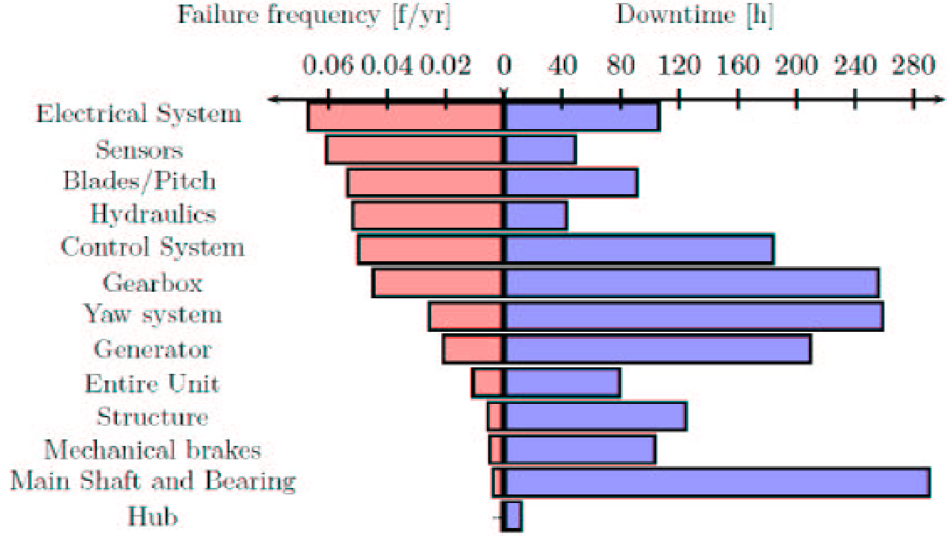
A reliability-centered maintenance method for assessing the impact of maintenance in power distribution systems, Bertling, Allan, Eriksson, IEEE Trans. on Power Systems, Vol. 1, 2005.

Examples:
RCAM for wind power systems

Wind open possibilities for sustainable energy supply

Picture: L. Bertling, F. Besnard at Smöla, August 2007.

RCAM – Stage 1 Critical components

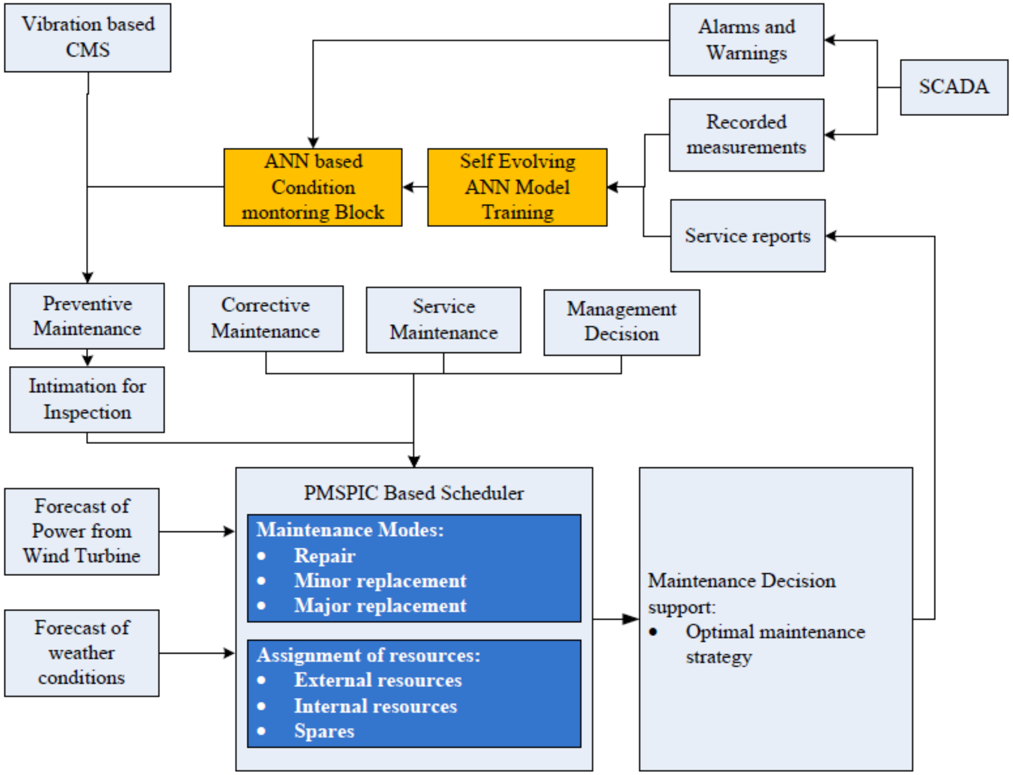


(Adapted from "Survey of failures in wind power systems with focus on Swedish wind power plants during 1997-2005", J. Ribrant and L.M. Bertling, IEEE Transaction on Energy Conversion, vol.22, num.1, 2007)

- Outage data used to identify critical components in the system
  - Unavailability = failure frequency * outage time
- ✓ Need for optimizing maintenance especially offshore where transportation costs are high and accessibility constrained by the weather

RCAM – Stage 2 Fault detection

- A framework is proposed for AM of wind turbines with ANN based CM approach using data from SCADA



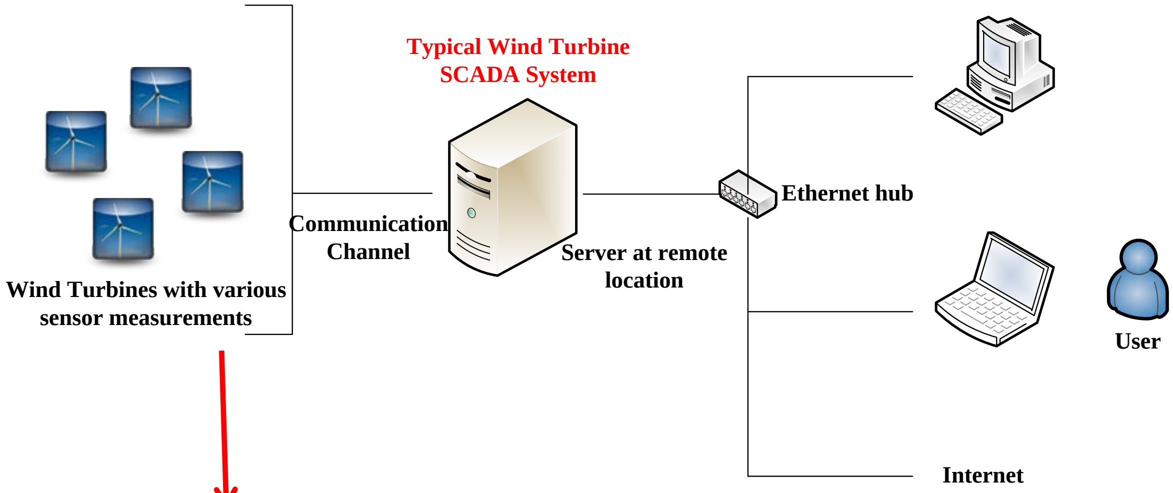
ANN: Artificial Neural Networks

PMSPIC: Preventive Maintenance Scheduling Problem with Interval Costs

SCADA: Supervisory Control And Data Acquisition system

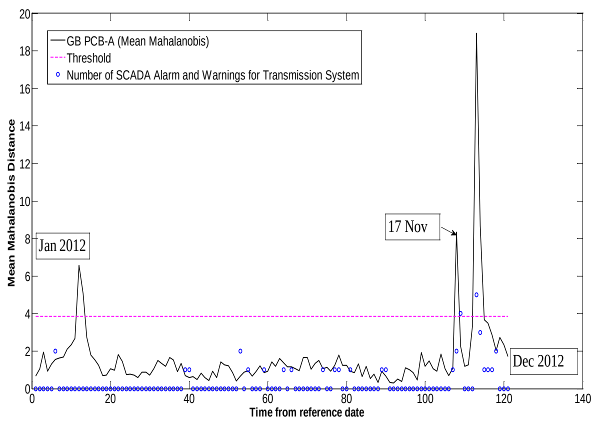
Bangalore P., Bertling Tjernberg L, An artificial neural network approach for early fault detection of gearbox bearings, IEEE Transactions on Smart Grid, Vol. 6, No. 2., March 2015.

RCAM – Stage 2 Fault detection



Automated training of ANN

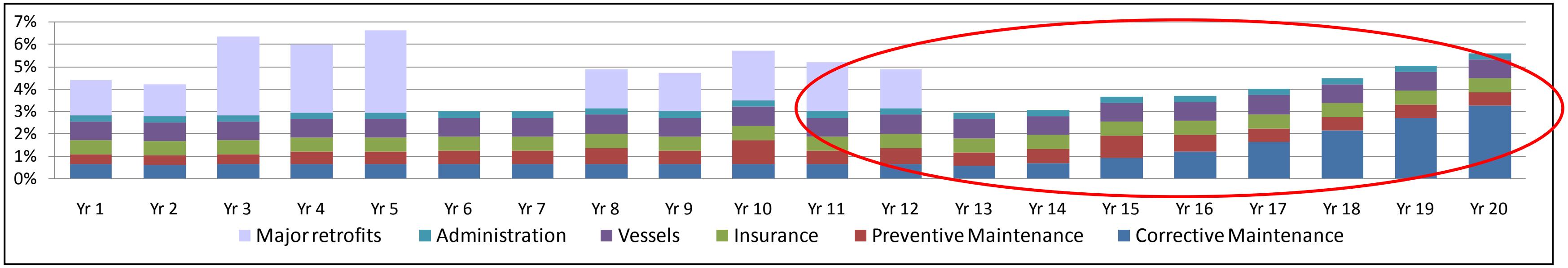
ANN based Anomaly Detection

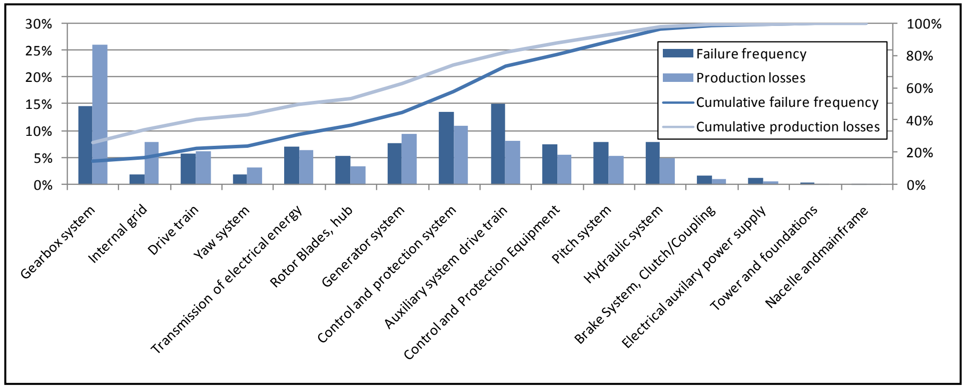


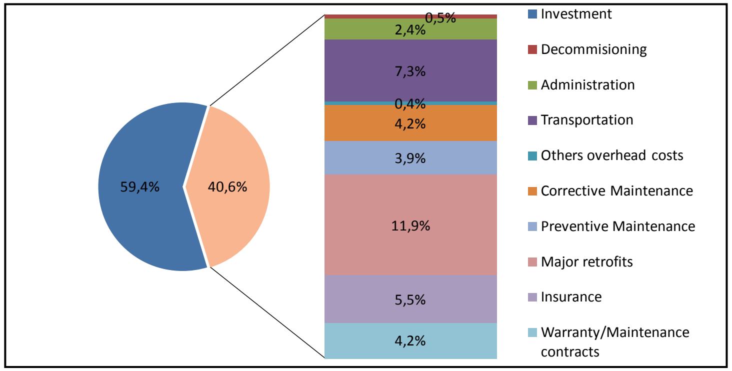
Bangalore P., Bertling Tjernberg L, An artificial neural network approach for early fault detection of gearbox bearings, IEEE Transactions on Smart Grid, Vol. 6, No. 2., March 2015.

RCAM Stage 3 – Life Cycle Cost Analysis

Case study based on Horns Rev (80 Vestas V80 2MW in operation, 2002)







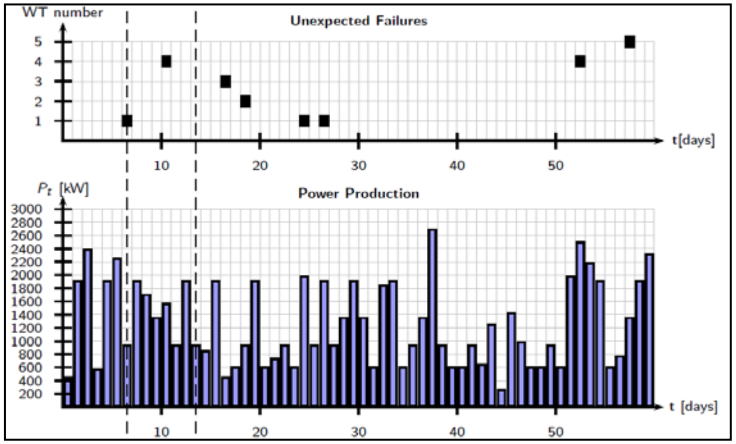
A Model for the Optimization of the Maintenance Support Organization for Offshore Wind Farms, Besnard F., Fischer K., Bertling Tjernberg L, IEEE Transactions on Sustainable Energy, April 2013.

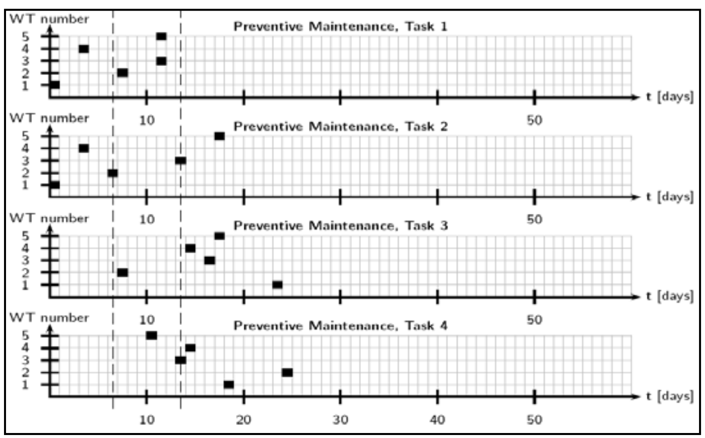
RCAM stage 3

- **Main idea:** scheduled service maintenance is generally performed at fixed time period without consideration for power production. This model would take advantage of opportunities at failure and low production forecasts to reduce transportation and production losses.
- **Objectives**: to perform service maintenance tasks at the lowest cost possible with following constraints:
  - perform the service maintenance activities within a time window (larger than the fixed time period)
  - inaccessibility in case of harsh weather (specially wave height), or use of the helicopter (if cost efficient)
- **Approach**: the model is a stochastic mixed integer linear problem.

A stochastic model for opportunistic maintenance planning of offshore wind farms", Besnard, François; Patriksson, Michael; Strömberg, Ann-Brith; Wojciechowski, Adam; Fischer, Katharina; Bertling, Lina, In proceeding of *Powertech 2011, Trondheim,19 -23 June 2011*

RCAM stage 3





- ✓ Failures are always fixed when they occurs (if accessible) and transportation should be used to perform other service maintenance activities.
- ✓ Results: Transportation and production losses costs reduced by 7170 €: 32% cost reduction → 20 years lifetime 143,000 €
- ✓ Practical limitation due to the size of the problem: Advance solvers or heuristic optimization methods

Summary conclusions

- It is beneficial to perform AM based on the results of quantitative systematic techniques such as RCAM and LCC
- New solutions with use of data from CMS and SCADA could be used for AM and RCAM analysis – *Smart Grid*
- There are challenges to overcome:
  - Handle roles of contractor and subcontractor, and organizations with lack of resources and knowledge
  - Relating maintenance effort and reliability benefit is complicated and there is a general lack of data
  - Handle data of large volumes
  - New tools are needed for the evaluation

THANKS & WELCOME!

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