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Workshop on
Optimization of Maintenance Activities Models, Methods and Applications

Maintenance Management of Sustainable Electric Power Systems

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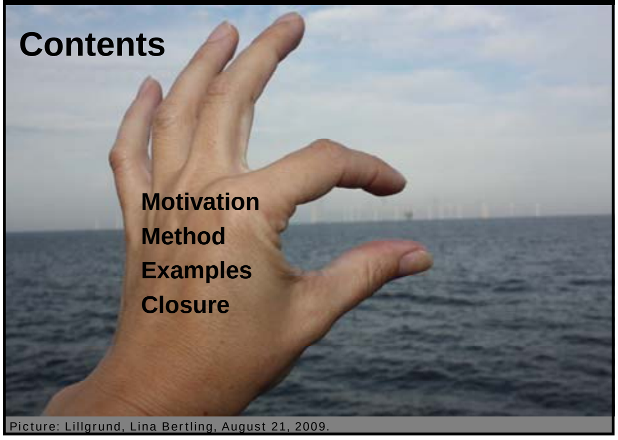

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Closure

Picture: Lillgrund, Lina Bertling, August 21, 2009.

Chalmers for a sustainable future

MISSION

A forward-looking university of technology with a global outlook that conducts internationally recognised education, basic and applied research and collaborations, integrated with a professional innovation process

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Motivation: Energy system in change

- The energy system is undergoing a major global change
- Main driving forces are to meet the climate and energy goals and to counteract the economic crisis.
- In Europe the climate and energy goals taken in Dec 2008 with target for 20/20/20 by 2020.

➢ Sweden: large increase in investment in wind power in large and small scale. (*Planning goal to 30TWh in 2015, from today's ~3 TWh. (total ~146 TWh)*)

➢ The electric power system and new electricity generation are facilitators to meet these changes by "*more and different use of electricity*"!

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Electric power system: challenges & solutions

Picture: Lillgrund Vattenfall, view from a 2.3MW turbine, by Lina Bertling, August 21, 2009.

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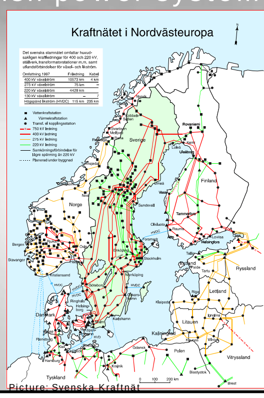
Motivation: the Swedish power system

Development phases:

- *1950's and 1960's*
  Expansion to facilitate the large hydro power development in the far north
- *1970's and 1980's*
  Expansion in the south caused by connections of nuclear power plants
- *1990's -*
  Increased capacity for international trade.
- 2005 –
  Reinvestments and increased focus on reliability
- 2008–
  Climate goals , renewable energy!



Picture: Svenska Kraftnät

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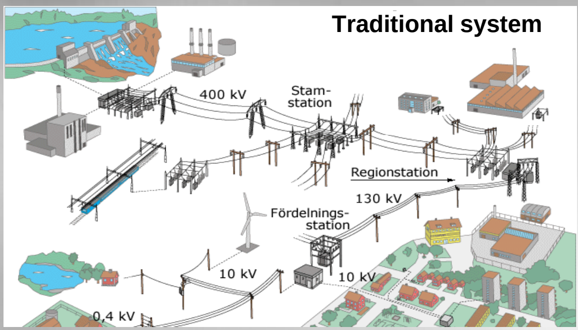
Motivation: complex power system



➢ **Towards more diversity and communication!**

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Motivation: power system challenges

Challenges for the electric power system:

- ➢ need of reinforcement in the power grid
- ➢ more integration between the countries
- ➢ more intermittent power
- ➢ more large and small scale production
- ➢ active customers with more information and being both consumer and producer

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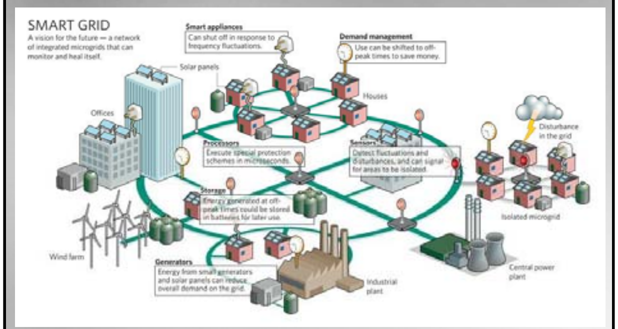
Motivation: smart power system



Source: www.nature.com/news/2008/080730/images/454570a-6.jpg

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Motivation: maintenance management

- Maximal asset value and minimal life cycle cost are examples of stated tasks of the electric power system managers
- These tasks are constrained by the requirements of customers and regulators concerning the reliability and quality of power supply.
- Equipment maintenance is one of the tools for handling reliability either by preventive (PM) - or corrective maintenance (CM).
- ➢ Maintenance management for ”optimal solutions”!

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Electric power system: maintenance management

Picture: Lillgrund Vattenfall, maintenance , by Lina Bertling, August 21, 2009.

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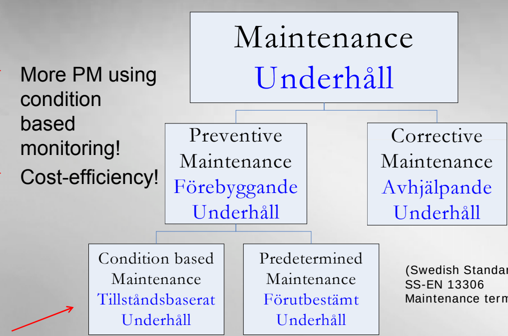
Method: maintenance management

- ➢ More PM using condition based monitoring!
- ➢ Cost-efficiency!



(Swedish Standard SS-EN 13306 Maintenance terminology)

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Method: RCM

- Reliability-Centered Maintenance is a systematic risk based qualitative approach 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.
- ➢ RCM does not add anything new in a technical sense. It is a new working process.

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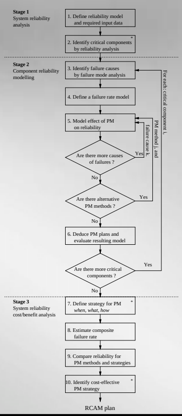
Method: RCAM

- The Reliability Centred Asset Management approach (RCAM) is a quantitative approach of RCM.
  - ✓ 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.

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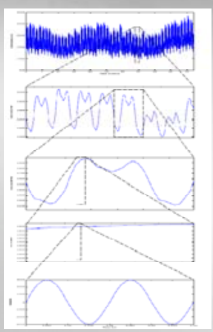
Method: power system modelling

Power system operation and planning –
➢different time scales and approaches!



Year

Week

Day

Hour

Millisecond

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Example: summary of main issues

- Maintenance management of electric power systems
  1. Design:
     - Is it possible to eliminate maintenance needs?
     - How can the power system be built to maximize availability at lowest cost?
  2. Operation and maintenance:
     - How can the life time be maximized?
     - How can the maintenance cost be minimized?
     - How can information and experience be used for planning maintenance e.g. using CMS

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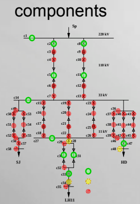
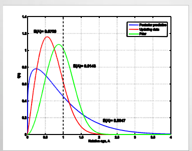
Example: RCAM case studies

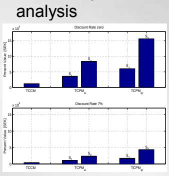
Stage 1: System reliability assessment and identification of critical components

Stage 2: Component reliability modeling outgoing from causes of failures

Stage 3: System analysis implementing maintenance strategies and performing cost analysis







Sources: "Maintenance Optimization for Power Distribution Systems", P. Hilber 2008, "On reliability and maintenance modelling of ageing equipment in electric power systems", T. Lindquist 2008 and "RCM for electrical power distribution systems", L. Bertling, 2002., all Ph.D. Theses from KTH.

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Example: RCAM case studies, stage 2

- The transformer is a critical component in the electric power system; critical function, capital and maintenance intensive.
- Pre-study on life time estimation of oil insulated power transformers, with use of condition monitoring data from gas analysis. (Franzén, Karlsson, Bertling, 2007)
  - ✓ Failure Modes and Effects Analysis (FMEA) was made to evaluate potential failure modes, their effects and causes.
  - ✓ Dissolved Gas Analysis (DGA) was studied as a tool to detect faults at an early stage
  - ✓ Conclusions; actual and difficult question and more work is needed to solve Stage 2.

Example: RCAM case studies, stage 2

- Results from the FMEA (Franzén, Karlsson, Bertling, 2007) for the power transformer:

Component	Function	Failure mode	Failure causes
Bushings	Connect windings to the work.	Short circuit	External contamination. Water ingress
Core	Wear magnetic field	Loss of efficiency	DC Magnetization
Solid insulation	Insulation of windings	Can not supply insulation	Overload. Oil deterioration.
Transformer oil	Isolate and cool the active part	Overheated oil. Contamination of oil	Oil deterioration. Ageing Short circuits
Tank	Enclose TRAFO oil. Protect the active part.	Oil leakage	Corrossion Careless handeling
Tap selector	Regulate the voltage level.	Can not change voltage level	Wear
Diverter switch	Maintain a coherent current	Contact failure	Contamination of oil. Lack of maintenance
Windings	Conduct current	Short circuit	Transient overvoltage Hot spot Movement of TRAFO
Cooling system	Cool the active part	Temperature rise	Wear

Example: wind power maintenance management

- Wind power is a central component in sustainable power supply
- Problem: high maintenance cost, impeding the growth of wind power
- Maintenance not optimized: large potential savings by reducing
  - cost for maintenance activities and component failure
  - cost due to production losses

  especially for large offshore wind parks
- Solution: maintenance optimization using CMS
  - continuously monitor the condition of the WT equipment (vibration of the driveline, oil analysis for the gearbox,…)
  - detect incipient failure
  - determine the optimal time for maintenance work

Example: wind power maintenance management

Research Elteknik: DC-networks for wind farms

Background:
- dc needed for longer transmission systems
- dc/dc-transformers have much lower weight than classical transformers

Objectives:
- To design a park
- To derive control of a park
- To study efficiency
- To make it fault tolerant

Possibility to remove the platform => huge cost savings

Sources: Lena Max,Ph.D. Theses from Chalmers, presented 8 December 2009.

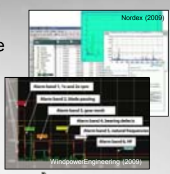
Example: wind power maintenance management

- Scheduled service maintenance is generally performed at fixed time period without consideration for power production.
  - **Objective**: To perform service maintenance tasks at the lowest cost possible
  - Main idea: To take advantage of opportunities at failure and low production forecasts to reduce transportation and production losses
  - **Approach**: The model is a mixed integer linear problem.

➤ Presentation by: PhD student Francois Besnard

Example: wind power maintenance management

- RCM application study for a real wind turbine
- Investigate the capabilities of the CMS and the methods used for maintenance management
- Develop an approach for using the CMS information to optimize maintenance decision, as part of a RCM program



- Based on results from above tasks:
  - Formulate recommendations from a user perspective on the use of CMS
  - Estimate cost benefits of CMS systems for wind power applications based on real data

New project: Dr. Katharina Fischer, Prof. Lina Bertling

Conclusions: mm electric power systems

➤ Reliability theory and applications to PM provides efficient tools for maintenance management.
- it is beneficial to apply maintenance strategies based on the results of quantitative systematic techniques such as RCAM
- potential savings with “optimal solutions”

➤ Several challenges to overcome:
- lack of input data in detail and range
- tools are needed for the evaluation
- roles of contractor and subcontractor “knowledge”

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Conclusions: mm electric power systems

Do not give up!

Picture: Visit at Smöla Wind farm, Statkraft, Norway, November, 2005

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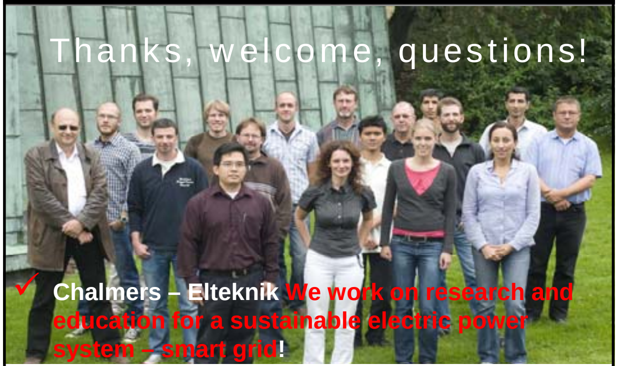
Thanks, welcome, questions!



- ✓ **Chalmers – Elteknik We work on research and education for a sustainable electric power system – smart grid!**

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Picture: Division of Electric Power Engineering, by J-O Yxell, August, 2009