VALUABLE MAINTENANCE OF HYDRO POWER

A review of 20 years of Norwegian R&D in hydropower maintenance



Outline

- Background
- Key results
- Failure model
- Success criteria





Hammern hydropower plant





Operational since 1900 Upprating 1927





Hydropower in Norway

Around 1400 power plants, around 2000 units Installed capacity 30 172 MW Annual production 130.2 TWh



Average age ~ 43 years





20 years of collaborative R&D in hydro O&M

- Maintenance systems (1992-1997)
- Technical operation and maintenance (1997-2001)
- Decision tools for maintenance planning (2001-2005)
- Value added mainenance in power production (2006-2010)







| 1986 Kvilldal kraftverk satt i drift | | 1991 Energiloven vedtas | 2001 Statministerens nyttårstale | | | | 2011 Dagmar og Berit setter fokus på klima | | | |
|--|------------------------------|---|---|-----------------------------------|---------------------|---------------------------|---|-------------------------------|------------------------------|-------------------------|
| 1978 RCM begrepet brukes første gang. | 1988 NEBB blir del av ABB | 1990 Datamaskinbaser vedlikehold tas i bruk. | rt 1999 Kværr kjøpt opp av | ner Energy v GE | 2002 No etablere | ord Pool es | 2010 I fyllings | Rekordlav sgrad | 2012 Elsertfikat innføres | 2020 EUs fornybarmål |
| | Vedlikeholdsad | dministrasjon Målst | tyring Ris | iko | Sviktn | nodell | | Analy | ysemiljø | |
| | | Vedlikeholdssystemer (1992-1997) | Teknisk drift og vedlikehold (1997-2001) | Beslutningsstøtte for vedlikehold | (2002-1002) | Verdiskapende vedlikehold | (2006-2010) | FRAM & SysLife (2011-2013) | | |
| 1980 | 199 | 0 | 200 | 00 | | | | 2010 | | 2020 |



Hydropower maintenance towards 2030



- To develop scenarios for
 hydropower in Scandinavia
 in general, and maintenance
 and rehabilitation in
 particular.
- To identify new technical, organizational, commercial and regulatory solutions and products.
- To identify need for new knowledge to meet future challenges.



Common features

- Some of the scenarios have common features
 - Inflection point (negative \rightarrow positive)
 - Climate changes
 - Green energy
 - Peak power has high value
 - Recruitment problems
 - Competence building
 - Large energy companies
 - Maintenance
 - Continuous monitoring
 - Pit stop maintenance
 - Hydropower will still play an important role in the energy system in 2030







Conclusions

- Scenario process resulted in
 - 93 mini scenarios, 5 main scenarios
 - List of challenges and recommendations for the hydropower industry in Norway and Sweden
- Scenarios can be used to create a basis for
 - identification of challenges, possibilities and restrictions
 - robust decision under uncertainty
- Easy to involve different persons / groups
- Challenge to distance oneself from daily routine to become creative
- Process requires good management and guiding



Key results

- Maintenance philosophy
- Decision tools
 - Technical-economic model
 - Multi-criteria decision aid
 - Optimal Maintenance Toolbox v 3.0
- Testing of maintenance paradigm
 - RCM
 - Online monitoring
 - 5s
 - Pit stop
 - WCM







World class maintenance

Maintenance management processes according to a draft European standard prepared by CEN / TC 319 / WG 8 Resources





Failure model





Technical condition states

- The condition development is often observable
- Condition monitoring handbooks by Energy Norway used to classify the condition

| State | Description |
|-------|--|
| 1 | No indication of degradation ("as good as new") |
| 2 | Some indication of degradation. The condition is noticeably worse than "as good as new". |
| 3 | Serious degradation. The condition is considerably worse than "as good as new" |
| 4 | The condition is critical. |
| 5 | Fault state. |



Lifetime model

Linking the 5 states with the life curve:





Expert judgement tool

| Skjema for eks | pertv | urdering | | | | | | | |
|---|---|---------------|---------------|---------------|---------------|----------|---------------------|-----------------|--|
| nr: 2 | Enhet: Mast / Stolpe Skadetype: Råte i jordbånd | | | | | | | | |
| 5. Varighet og spredning for tilstand 1 - 4 | | | | | | | | | |
| Tilstand: | | T1 | T2 | ТЗ | T4 | Т | Kommentarer | | |
| Typisk varighet for tilstand: | [år] | 20 | 15 | 8 | 2 | 45 | | | |
| 10%-kvantil: | [år] | 14 | 10 | 5 | 1 | | 1 | | |
| Standardavvik | [år] | 4,9291 | 4,1389 | 2,5088 | 0,867 | [| | | |
| alpha | [år] | 16,4638 | 13,1345 | 10,1685 | 5,3209 | 0,07 | | 1,20 | |
| beta | [år] | 1,2148 | 1,142 | 0,7867 | 0,3759 | 0,06 - | | 100 0 | |
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Results from the model

Calculation of failure probability



Calculation of expected remaining life Simulation of condition development







Case - Eidsiva: Planning of maintenance work at Osa power plants using elements of pit stop methodology









Case – SN Power

- Global maintenance strategy
 - RCM analysis
 - Systematic use of indicators
 - Contious improvement
- Methods and tools from the maintenance projects

Norwegian origin, global application



System collecting and sharing life time data (SysLife)





Framework for risk and profitability analysis based on tehcnical condition (FRAM)





Success criteria

- 1. Collaborative research project
- 2. Active involvement from the power companies
- 3. Support from the national research council
- 4. Training courses, seminars and workshops





The bottom line

Cost (2012 US\$):

Power companies: National research council: **SUM:** 8.0 mil. US\$ 4.8 mil US\$ **12.8 mil US\$**

"Correct implementation in our own organization will over time give an 20% added value to our maintenance."

Statement from user group

Potential added annual value of maintenance: 128 mil US\$



