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What should a condition monitoring system look like for a tidal turbine ?

Presented to: International Conference on Ocean Energy (ICOE) 2016
EICC, Edinburgh
23th Feb 2016, Day 2 - Session B7

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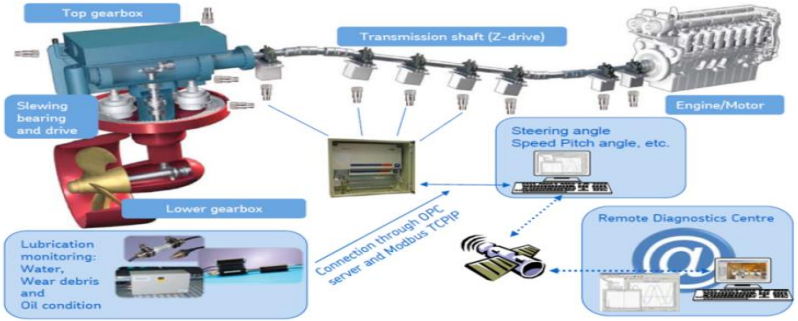
SKF®

SKF – a truly global company

- Established 1907
- Sales 2014 SEK 70,975 million
- Employees 48,593
- Production sites around 165 in 29 countries
- SKF presence in over 130 countries
- Distributors/dealers 15,000 locations
- Global certificates ISO 14001
  OHSAS 18001 certification
  ISO 50001

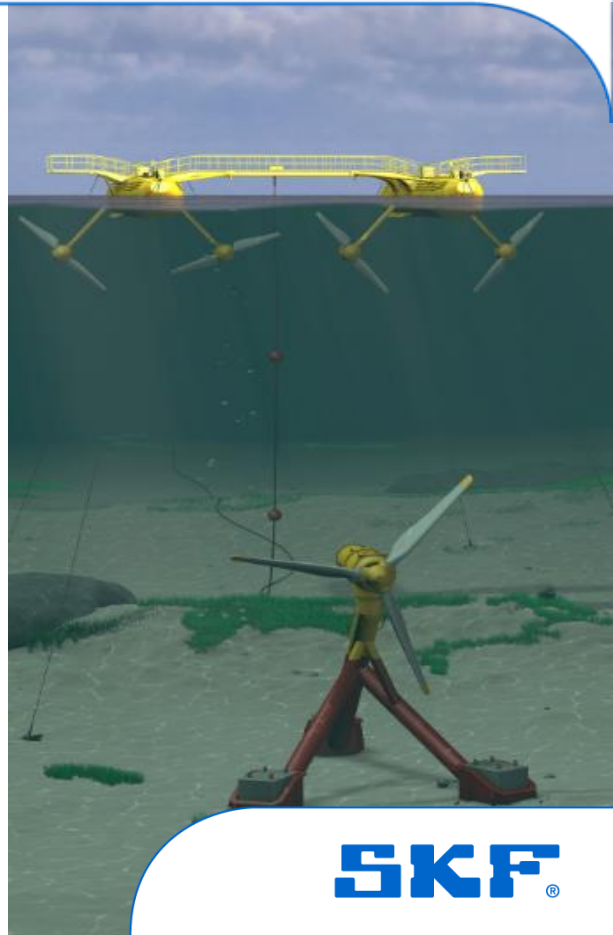
Introduction

- Effective condition monitoring in tidal turbines
- Utilising experience from wind, marine, oil & gas and also early prototype data logging
- Condition monitoring strategy
- Technology
- Establishing an effective scheme for analysis and reporting
- Taking it a step further to drive continuous reliability improvement



Create condition monitoring strategy

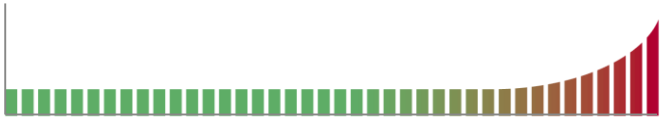
- The aim is to establish a cost effective condition based maintenance (CBM) program
- Clear understanding of failure modes, effects and their criticality
- How the failure modes manifest themselves in the form of changes in vibration, temperature, pressure, flow etc.



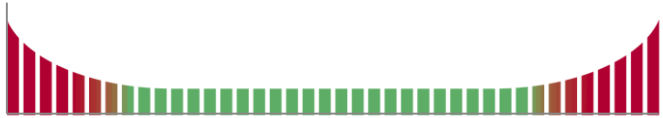
The reality of failure modes

There are six failure patterns

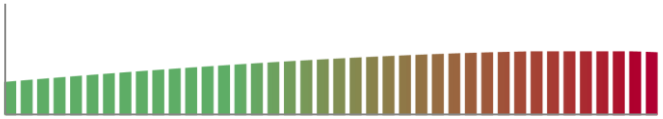
20% time related



Pattern A - Traditional (age related)

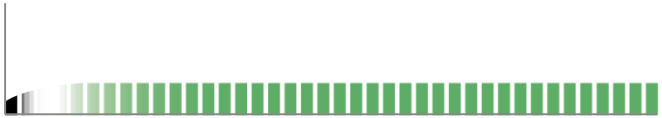


Pattern B - Bathtub curve

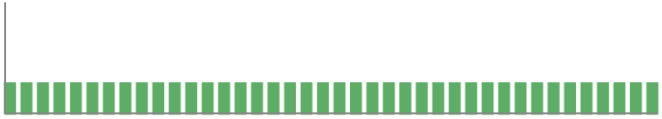


Pattern C - Fatigue induced

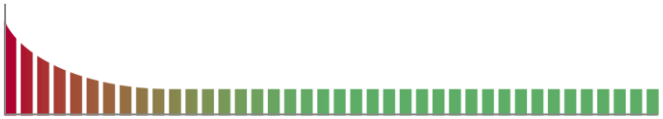
80% random



Pattern D - Initial wear-in period



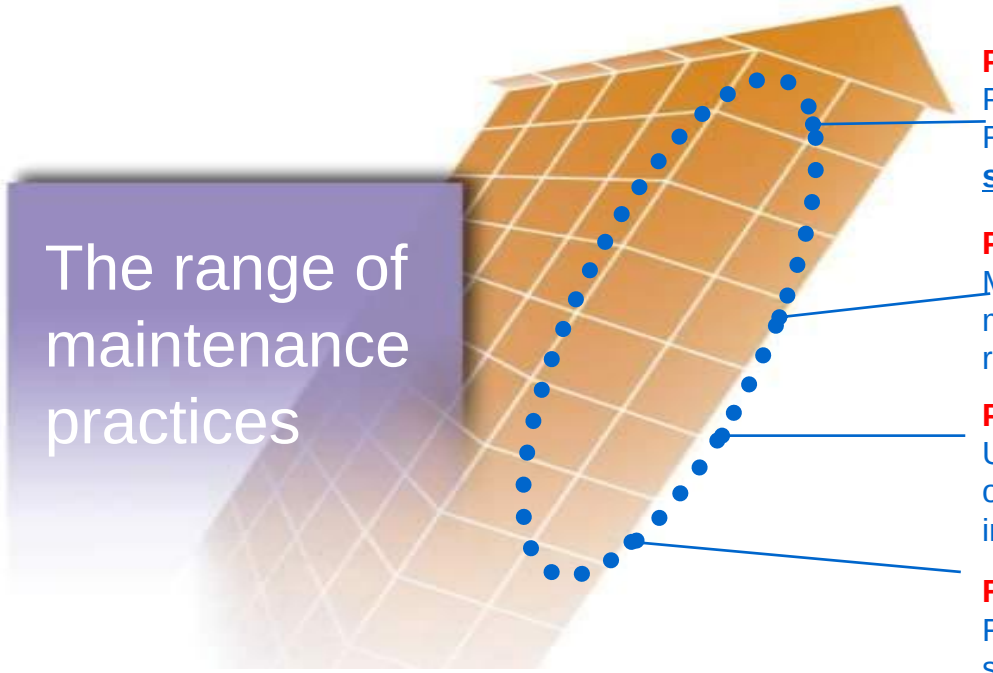
Pattern E - Random failure



Pattern F - Infant mortality

The **majority of failures are random**, not time-based and in some cases maintenance can induce failures

Reliability-focused maintenance practices



“WorldClass”

Proactive Reliability Management (PRM)
Predictive maintenance applied to **critical** machines; Root causes identified with view to finding long term **solutions** to improve reliability. √

Predictive Maintenance (PdM)
Machine condition assessed using condition monitoring technologies; unplanned shutdowns reduced. √

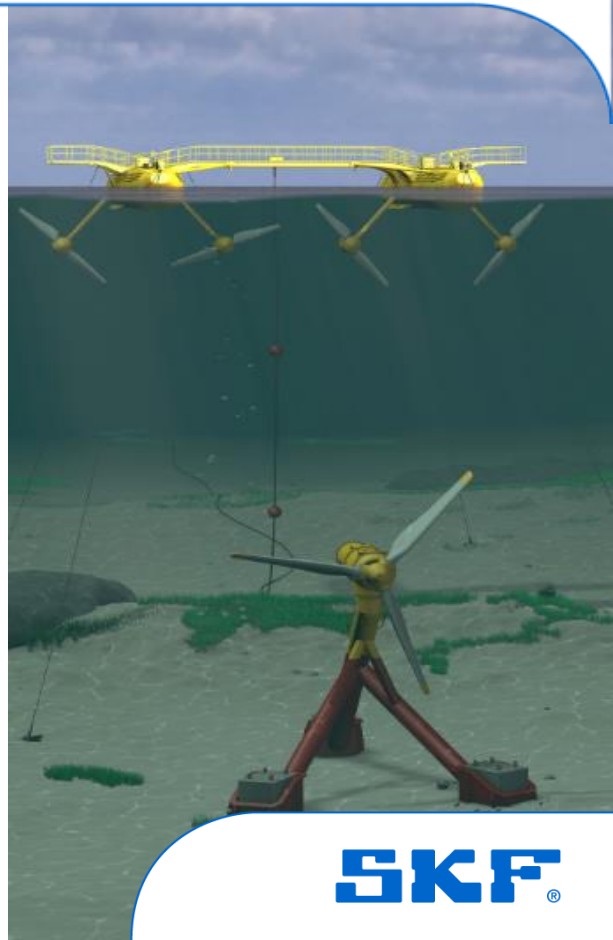
Preventive Maintenance(PM)
Unplanned and planned shutdowns. Scheduled overhaul of equipment at pre-determined time intervals. X

Reactive/Corrective
Fix it when it breaks approach; unplanned shutdowns occur when the machine breaks. X

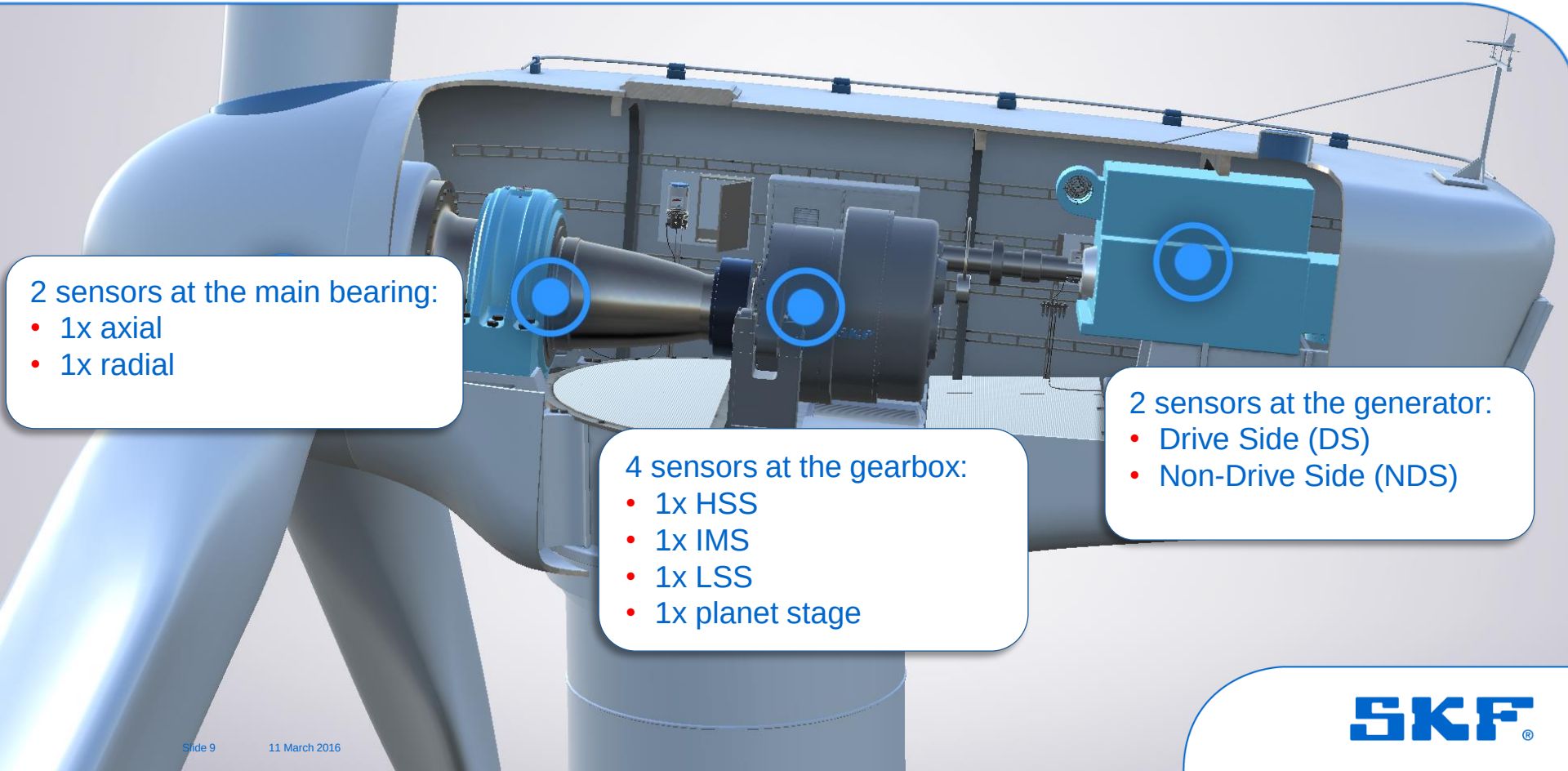
“Firefighting”

Implement condition monitoring strategy

- Need management buy-in
- Reliable monitoring systems/ measurements /sensors
- Remote diagnostic support



Drive train sensor arrangements

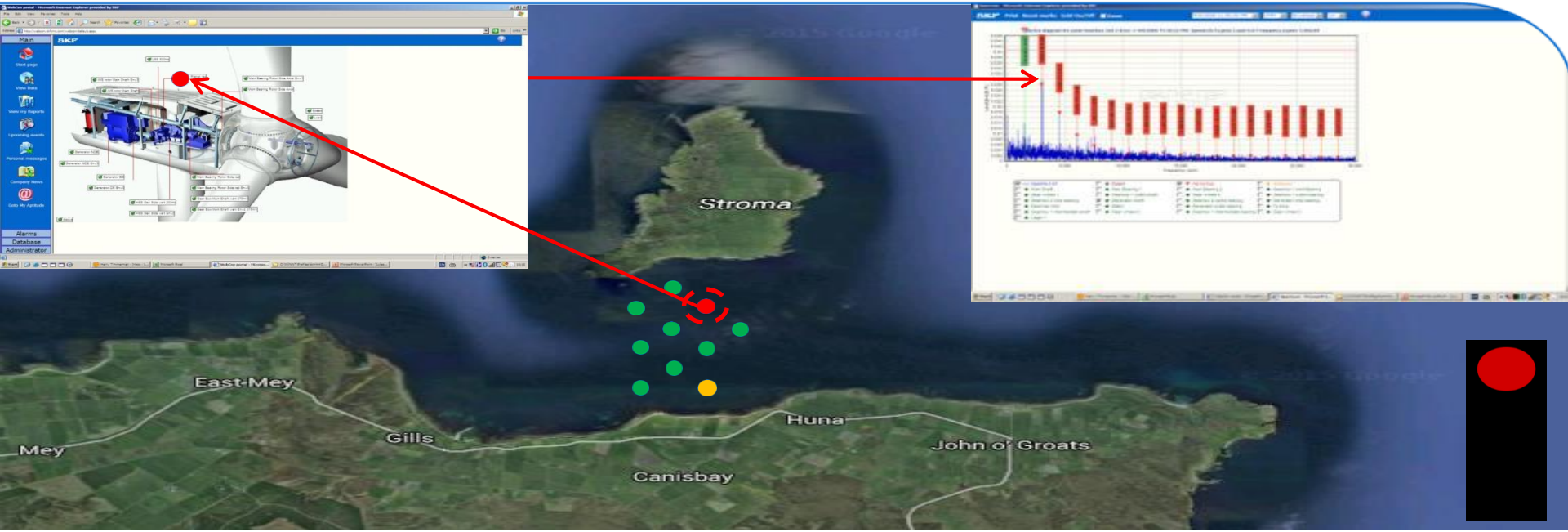


2 sensors at the main bearing:
- 1x axial
- 1x radial

4 sensors at the gearbox:
- 1x HSS
- 1x IMS
- 1x LSS
- 1x planet stage

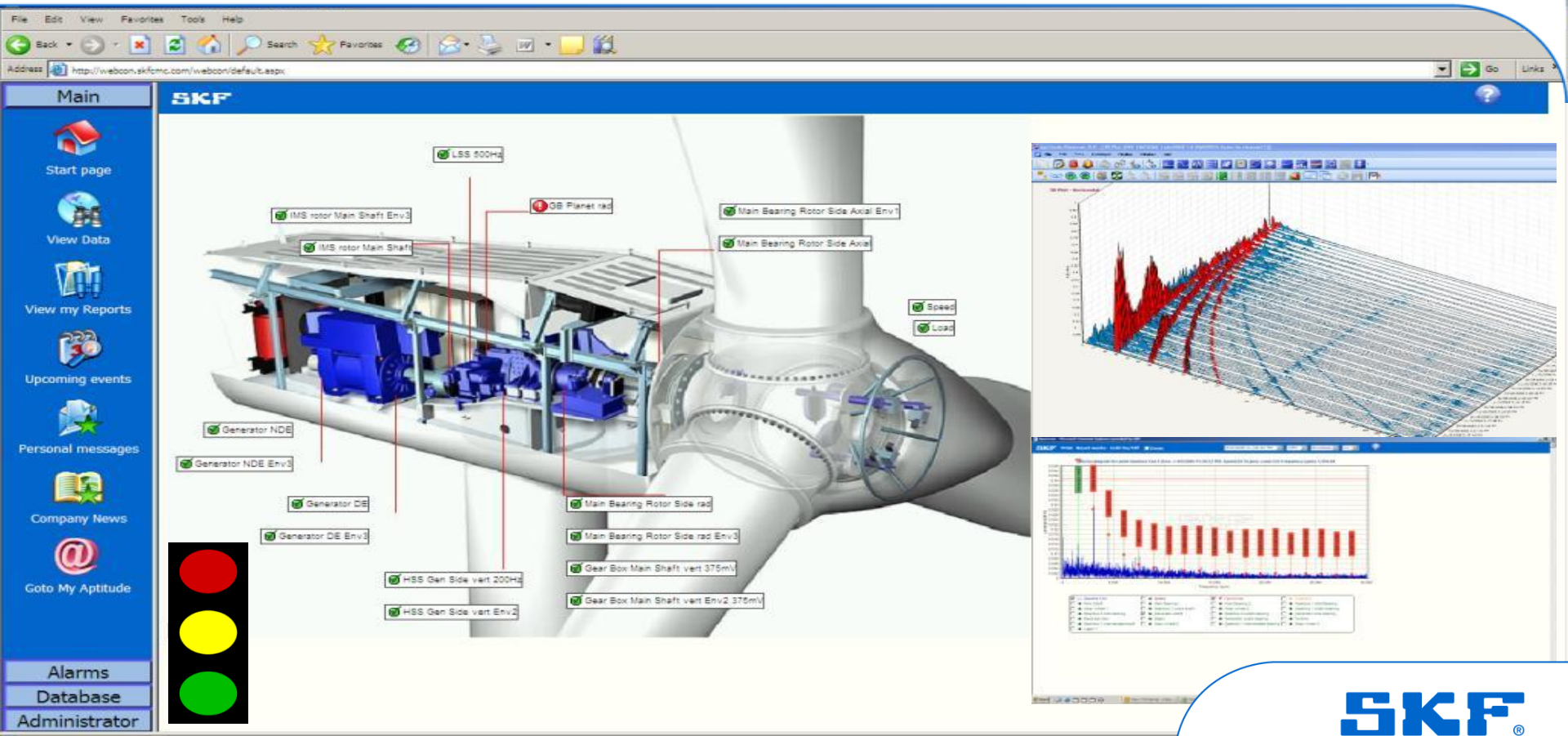
2 sensors at the generator:
- Drive Side (DS)
- Non-Drive Side (NDS)

High level human machine interface



- Web access from any computer with internet access
- User friendly with no special software or training required
- High level traffic light status
  - Ability to interrogate detail that sits below this

Human machine interface - diagnostics



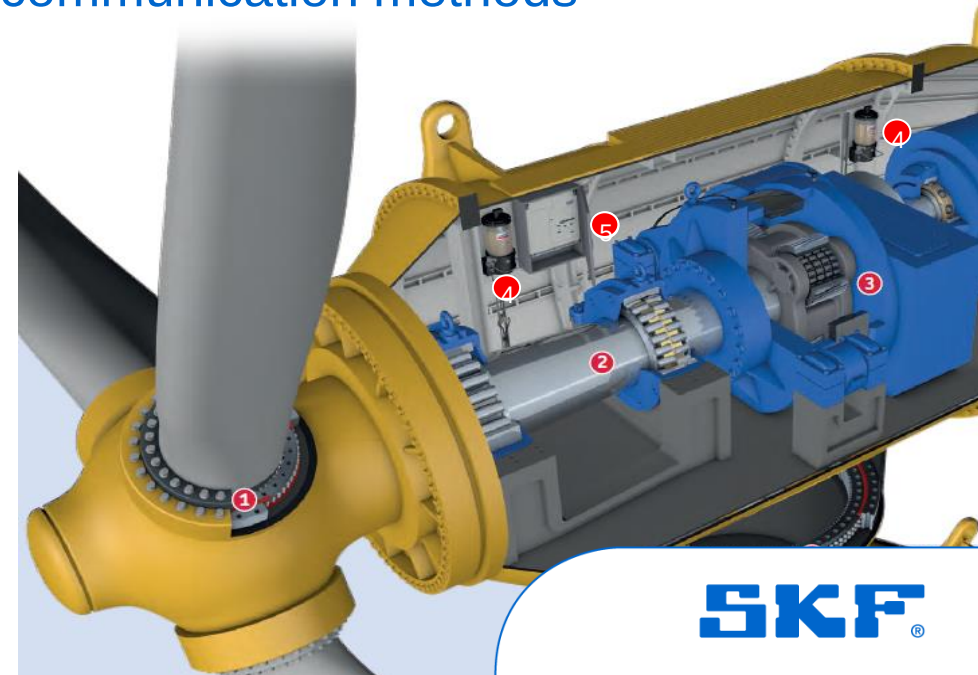
Technology

- Customise what we have but recognise the unique requirements for a tidal turbine application

- CMS in wind turbines and marine thrusters are designed to collect meaningful data allowing for variable rotating speeds and loads.

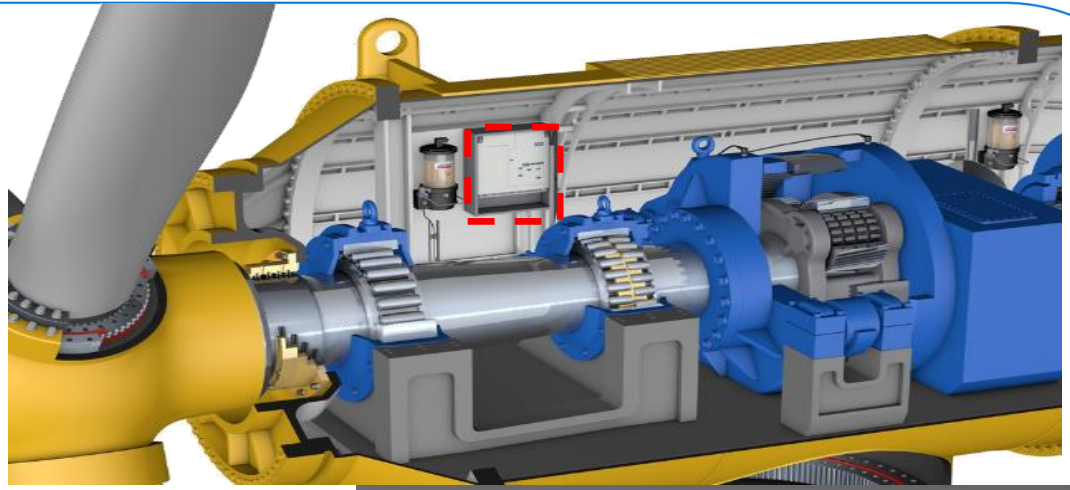
Requested by tidal stream turbine developers

- Reliable operation for up to 6.25 years
- Integration with Control and Instrumentation cabinet
- Accommodate different types of communication methods
- Power supply redundancy
- Options for AC and DC supply
- IP66 enclosure



Overview of typical fault diagnosis in wind sector which can be transferred to tidal turbines

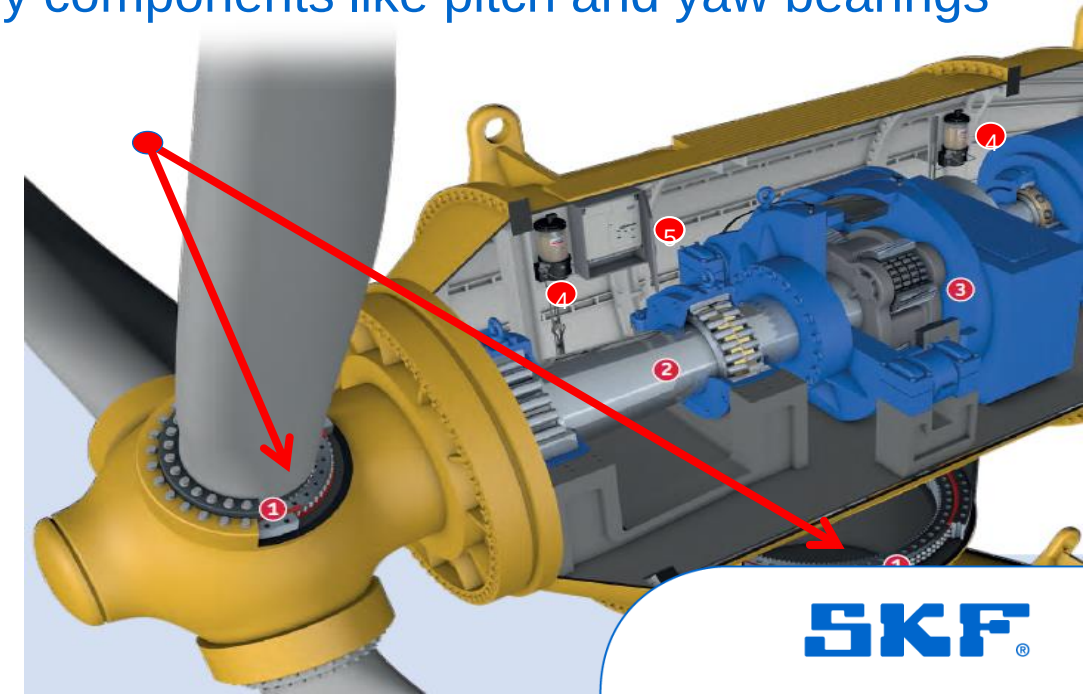
- Bearing condition
- Gear condition
- Misalignment
- Shaft deflections
- Mechanical looseness
- Resonance problems
- Tower vibration
- Blade vibration
- Electrical problems
- Generator rotor/stator problems
- Inadequate lubrication



Expanding the condition monitoring system scope

- Traditionally focus is on the main drive train
  - Main shaft bearings, gearbox, and generator
- Monitoring the condition of key components like pitch and yaw bearings is also of great interest

- This presents a bigger challenge as we only have partial and infrequent rotation
  - Requires special sensors and signal processing



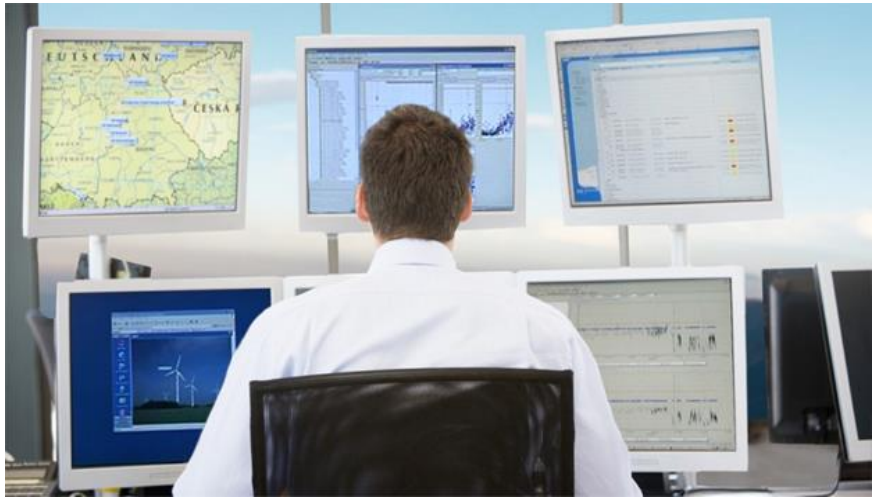
CMS robustness…. Class certified

- Lightning protection:
  EN61000-6-2:1999, EN61000-4-5: 4 kV
- Offshore: iMU has Stainless Steel Box IP65, Stainless Steel Sensor IP67
- For arctic versions temperature range extended to minus 30°C
  (Arctic tested to -60, ETL to -20)
- GL certified since the start of GL rulebook
- Certified for altitude of 3000m

SKF's thruster monitoring CMS is marine class certified by DNV.

Remote diagnostic function

- In- house (OEM) or outsourced
- Detection of developing faults
- Informed decisions, modifications to operational modes, maintenance deferral
- Web enabled reporting tool for effective communication of diagnostic results
- Use of “Rule Based” Decision support tools to carry out a first pass automatic diagnosis



Continuous reliability improvement

- Condition Monitoring detects but does not eliminate faults
- In the oil and gas sector, operators demand "**Continuous improvement**"
- Making use of "**Real Life History**" to improve reliability, availability and uptime
- Identification and quantification of "**Bad Actor**" machines

Proactive Reliability Management (PRM)

Act like "Reliability Engineers" not "Maintenance Engineers"

- Root Cause Analysis (RCA)
  - RCA processes should be applied day to day
    - In response to plant upsets and HSE incidents
    - Considers both technical and human causes
    - Resolution may be
      - Engineering solution
      - Change in procedure
      - Personnel training
- Root Cause Failure Analysis (RCFA)
  - Component Failures

Improve OEM Designs

“Lessons learned” from real life history in operations

- The CBM programme needs to capture reliability/fault history
- Codification of identified faults and exceptions
- Allows “benchmarking” of reliability performance
- Identification of “bad actor” machines and components
- Information used as an input to Root Cause Analysis (RCA)
- Field information used to help improve future OEM designs

Benefit summary of a condition monitoring system

- Proactive approach to maintenance
- Target maintenance effort where and when it’s needed. (condition based)
- Reduce risk of unplanned shutdowns and resulting loss of power production
- Predict remaining service life, thus extending time between interventions (retrievals)
- Consolidate maintenance activities and plan for repairs by tracking the failure mode
- Reduce plant operating costs and hence LCoE

Conclusions

- We can make good use of learnings from synergistic industries
- An optimised maintenance strategy requires a good understanding of failure characteristics.
- Studies have shown that around 80% of failures are random in nature meaning Condition Monitoring in the majority of cases is effective.
- Condition monitoring needs to be targeted at the critical equipment and components where undetected failures would impact on the business drivers
- Existing condition monitoring tools and technology can be customised for use in tidal turbines
- An onshore remote diagnostic function needs to be established, requiring ongoing management commitment and competent resources
- In operations having a tool that allow the capture of reliability/failure history is essential if we are to continuously improve machine designs

Thought for today

What you don’t measure, you cannot understand,

What you cannot understand, you cannot control,

What you cannot control, can cause pain.

What does Pain = 

Thank You
Questions?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