



CONDITION MONITORING

Ramboll's cost-optimal monitoring solutions ensure risk based inspection planning and longer life expectancies of wind farms.

The idea of monitoring a situation before it becomes critical is well-known in many fields of engineering involving machinery. Wind farm operators also choose to have condition monitoring performed on their entire wind farms, because:

- The structures have few and well-defined weak points
- There are a large number of similar structures
- Maintenance is expensive and complicated
- Proactive measures will limit expensive production stops

Ramboll has decades of experience in developing and operating custom-based monitoring systems for new and existing complex structures. These include offshore wind turbine jackets and monopiles, substations, oil and gas platforms, and civil structures like bridges, railways and buildings. As an independent consultancy,

we strive to deliver cost-optimal monitoring solutions that are custom-made.

We focus on low-cost sensor setups with few, optimal sensors. The data is then integrated into our monitoring system consisting of physical models, reflecting design knowledge and transforming the data into KPIs for O&M decision. A communication unit transfers collected data to remote PCs and a smart-unit, which processes measured data in real-time and sends warnings or alarms if changes occur.

Through numerous reference projects, we have demonstrated the capability of our algorithms to replace excessive instrumentation.

Consequently, our clients have:

- Cut the installation and hardware costs required for structural integrity monitoring
- Avoided over-maintenance actions

- Optimised the scope of inspection, focusing on the highest risks
- Increased their return on investment through continued operation.

Our experience and competences

Ramboll is an international engineering consultancy providing high-quality services in all phases of wind energy projects. Ramboll has outstanding expertise in planning, design and technical specifications of monitoring systems for wind farms, certification & authority approval, root cause analysis, fatigue reassessment, damage detection, cloud computing and automated monitoring reporting.

For further information, please visit www.ramboll.com or contact us directly:

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Monitoring system design and implementation

Ramboll has expert knowledge of the latest monitoring technology, stemming from recent monitoring projects and dedicated research. We deliver a wide range of services tailored to operator needs:

- Review of wind farm monitoring strategy
- Guidance on requirements, installation limitation and expected performance of state-of-the-art low cost monitoring solutions
- Detailed technical specifications of measurement equipment
- Optimal sensor layout studies
- Sensor specifications including recommended locations
- Implementation of analytical models for automated data analysis, including SCADA and environmental data
- Continuous supervision of data quality and periodic reporting on wind turbine conditions

Our clients benefit from Ramboll's long-term relationship with world leading measurement equipment providers.



Structural re-assessment for lifetime extension

Measurement data taken under real operating conditions are key to updating design assumptions. With renewed design calculations, Ramboll determines the remaining useful lifetime for the each wind turbine structure in the wind farm. Our services cover:

- Short-term measurement campaigns to determine real performance
- Update of finite element models, establishing digital twins
- Design validations
- Improved soil models
- Assessment of local fatigue issues
- Calculation of site-specific used fatigue life
- Online monitoring of continuous fatigue
- Operational lifetime predictions under real site conditions (e.g. corrosion, scour, soil degradation)

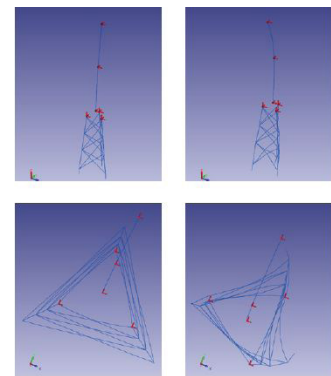
Our clients benefit from cutting-edge analytical methods that Ramboll has developed in-house.



Reliability and risk-based inspection planning

With more than 35 years in the offshore business, Ramboll has the right tools at hand to transform monitoring data into reliability and risk-based inspection planning. Our services for an efficient structural management comprise:

- Implementation of a true digital twin
- Supply of online damage detection tools that indicate changes in real time
- Assessment of structural integrity after occurrence of severe or unexpected events
- Analysis and assessment of maintenance needs after occurrence of severe or unexpected events
- Integration of condition monitoring data and inspection data into reliability and risk-based inspection planning
- Calculation of optimal inspection intervals
- Update of inspection planning based on inspection results e.g. from non-destructive testing



RELIABILITY BASED INSPECTION PLANNING

CLIENT

Vattenfall

LOCATION

Fredericia, Denmark

PERIOD

2011 - 2013

SERVICE PROVIDED

Implemented a low-cost structural degradation monitoring methodology, deliver information on the structural condition for reliability-based inspection planning.

REMAINING USEFUL LIFETIME AFTER DETECTION OF EXCESSIVE CORROSION

CLIENT

Offshore Wind Farm Operator

LOCATION

United Kingdom

PERIOD

2013 - 2014

SERVICE PROVIDED

Analysis of structural monitoring data to update fatigue life calculations. Recommendation on remaining useful lifetime and required O&M activities.

OPTIMAL SENSOR LAYOUT FOR AMBIENT VIBRATION MONITORING OF JACKETS

CLIENT

ScottishPower

LOCATION

London, United Kingdom

PERIOD

2016

SERVICE PROVIDED

FE model simulations to test the optimal number and location of distributed accelerations. Sensor layout designed to detect damages and hot spot loads.