ROME O
An ambitious project to reduce the cost of offshore wind energy

Wind Energy Science Conference - 18th June 2019
University College Cork, Cork

Elena González (elena.gonzalez.ext@siemensgamesa.com)
What is ROMEO?

ROMEO stands for Reliable OM decision tools and strategies for high LCoE reduction of Offshore wind

• H2020 Innovation Action for Societal Challenges
• 16.4 M€ Total Budget (~10M€ EU contribution)
• 5-year project (2017-2022)
• The consortium…
  ➢ Led by Iberdrola Renovables
  ➢ Formed by 12 partners across Europe
  ➢ Involves some of the most important players in the offshore wind industry
What is ROMEO?

- Adwen
- bachmann.
- University of Strathclyde, Glasgow
- EDF
- Ramboll
- Laulagun Bearings
- Uptime Engineering
- Siemens Gamesa
- Iberdrola
- IBM Research, Zurich
- Indra
- Zabala Innovation Consulting
ROMEO Project

What are the objectives?

The Project phases

Work description & packages

The progress: ROMEO to date

Summary & Future steps
What are the objectives?

Main objective: Reducing Offshore wind O&M costs through…

- Development and demonstration of an O&M information management and analytics platform
  - Better understanding of real-time behaviour of the main components under real operating conditions
  - Assess and maximize their lifetime
  - Facilitate the switch from corrective maintenance to condition-based maintenance strategies
  - Improve the decision making processes, such as scheduling maintenance activities or managing end-of-life scenarios.
- All leading to a minimised OPEX and a reduced LCoE
What are the objectives?

Greater reliability, less repairs, more safety

- Increase wind farm reliability and decrease the number of failures leading to downtime
- Increase the life time of key turbine components
- Reduce the WT O&M costs through the reduction of the resources required for annual inspections of the turbine
- Reduce the O&M costs associated to foundation through reduction in jacket substructures inspections
What are the objectives?

Technology Readiness Level (TRL) ⇒ 7

3% LCoE Reduction
ROMEO Project phases

01 Definition of the project technical specifications and requirements

02 Development of new monitoring systems as well as novel diagnosis and prognosis models for detection and prediction of failures affecting key components

03 Final validation of the data management platform
ROMEO Project phases

Three validation scenarios

PHASE 1
- Technical specifications and project requirements
- Wind turbine diagnosis/prognosis solution for a new design (physical)

PHASE 2
- Turbine fault offline failure models for a running design
- Structural condition monitoring
- Data acquisition & analytics ecosystem
- O&M information management platform

PHASE 3
- Pilot tests
- Impact assessment

Validation scenarios:
- Teesside
- Wikinger East
- Anglia
Work description & packages

WT SCALE
Components and structure

IT SCALE
Ecosystem, Platform & Environment

WF SCALE
Demonstration & Impact
Work description & packages

**WT Condition Monitoring**
- Detect degradation patterns related to critical failure modes
- Develop innovative DIAGNOSIS and PROGNOSIS solutions

**Health Structural Monitoring**
- Develop low-cost Structural Health Monitoring system for jackets & monopiles
- Assess RUL for lifetime extension purposes

**WT SCALE Components and structure**

**Data Acquisition & Analytics Ecosystem**
- Flexible & interoperable IoT platform
- Based on distributed processing

**O&M Information Management Platform**
- Intelligent reporting & visualisation
- Facilitate maintenance-decision making
- Asset management & advisory information

**IT SCALE Ecosystem, Platform & Environment**

**Pilot Tests Real scale implementation**
- Real time data integration
- On-site validation of developed solutions
- Testing Asset management tool

**Impact assessment & Replication**
- Quantification of innovative O&M practices against baseline
- Assessment of impact from using the developed solutions:
  - LCOE & OPEX reduction (%)

**WF SCALE Demonstration & Impact**
- Assessment of impact from using the developed solutions:
  - LCOE & OPEX reduction (%)
Work description & packages

WP9
Dissemination

WP1
Failure modes effect and criticality analysis (FMECA)

WP10
Project management

WP2
WT Diagnosis/Prognosis solution for a new design

WP3
WT offline failure models for a running design

WP4
Structural condition monitoring

WP5
Data acquisition

CORE of the ROMEO Project

WP6
O&M Information Management Platform

WP7
Pilot tests Real Scale implementation

WP8
Impact assessment (LCoE & Replicability)

WP10
Project management

WP1
Failure modes effect and criticality analysis (FMECA)

WP2
WT Diagnosis/Prognosis solution for a new design

WP3
WT offline failure models for a running design

WP4
Structural condition monitoring

WP5
Data acquisition

CORE of the ROMEO Project

WP6
O&M Information Management Platform

WP7
Pilot tests Real Scale implementation

WP8
Impact assessment (LCoE & Replicability)
WP1

- Failure Modes and Effects and Criticality Analysis (FMECA) for offshore wind turbines
- Identification of the most critical components and failure modes

337 failure modes identified for key WTG components and structure

120 investigated towards applicability of monitoring

60 of them with large potential benefit for monitoring systems to be further investigated

ROMEO to date

WP2

➢ Development of new tailored monitoring solutions for specific failure modes
➢ Study of degradation and failure symptoms and how to capture/measure them at test bench scale, for testing & improvement purposes.

Main Bearing & Gearbox
- New detector to account for Displacement Sensors.
  ✓ Early detection techniques diversification.
- Damage Classification Technique.
  ✓ Better understanding of failure mode and effects.
- Imbalance Detection using Vibration Sensors.
- RMS Vibration calculation for Gears & Bearing

Blade Bearing
- New Diagnosis & Prognosis algorithms for:
  ✓ Rolling Contact Fatigue;
  ✓ Structural Health Monitoring of the rings.
- Tests running @ WINDBOX

Electrical Drive Train
- Forthcoming tests to be run @ EDF Electrical Lab
ROMEO to date

WP3

- Aims at developing a full set of cost-effective diagnosis and prognosis failure mode oriented solutions
- In-Depth investigation of component real behaviour & failure symptoms as observed in SCADA data
- Risk-based Diagnosis & Prognosis (D&P), implying important advances beyond the State-of-the-Art
- Ensure portability to contribute to enhance the understanding of failure occurrence in offshore wind farms

Wikinger Wind Farm – Adwen AD5-135
- Selection of the 13 most critical failure modes
- Development of advanced D&P Physical Models for these 13 Failure Modes
- 5/13 diagnosis models running daily

Teesside Wind Farm – Siemens SWT2.3
- Selection of the 9 most critical failure modes
- Development of advanced D&P Physical Models for these 9 Failure Modes
- 4/9 diagnosis models running daily

Physical models to be combined with Machine & Deep Learning models
ROMEO to date

WP4

➢ Focus on improving structural health monitoring approaches
  • Review of monitoring technologies and specification of the support structure monitoring problem for offshore wind farms
  • Selection of the most appropriate monitoring technologies for each of the failure modes identified as part of the FMECA.
  • Optimal sensor placement study for Wikinger OSS and one foundation

  Short-term measurement campaign on going
  Some data retrieved already from the permanent monitoring system

  FEM Update and benchmark of low-cost monitoring techniques

Andalucía OSS at Wikinger site

Equivalent Digital Twin
ROMEO to date

Digitalization and data integration

➢ Challenging integration of the different data acquisition and processing elements and protocols:
  • Heterogeneity of variables to monitor and process
  • Multiple communication infrastructures: interfaces and protocols have to be independent from the communication infrastructures
  • Communication protocols: need to cope with the variety of subsystems and strategies involved in the control of the elements participating in the WT subdomain
  • Real time data processing: allowing extreme transactions and processing characteristics based on the novel edge computing paradigm
  • New flexible and interoperable IoT cloud platform
System architecture for Wikinger Wind Farm
ROMEO to date

Development of an Information Management Platform for easing maintenance-related decision processes

WP6

Degradation Analytics Engines

Historical Data
- Inspection Data
- Environmental Data
- Operational Data

Uptime Data Examination
- Event Based Reasoning
- KPI Calculation

O&M Information
- Analytics Modules Results
- Monitoring

Uptime Advisory Generation
- Failure Diagnosis
- Maintenance Process
- KPI (Availability, MTTF, Statistics)
ROMEO to date

WP8

- Wide-applicability, modular, open-access tool for the simulation of O&M activities of offshore wind farms
  - Costs & revenues throughout the life cycle of the assets are considered, allowing for alternative KPIs to be considered
  - Real value of cash-flows is taken into account
  - Stochasticity of certain inputs is integrated through Monte-Carlo sampling to assign confidence levels in the assessment
  - A flexible O&M evaluation model is incorporated for a fully integrated, robust analysis.
ROMEO to date

**WP8**

**Power data:**
- Power output curve
- Hub height

**Weather data:**
- Wind speed
- Significant wave height

**Cost input data:**
- Energy Price
- Interest rates

**Unplanned maintenance data (turbines and BoP):**
- Repair times
- Required crew number
- Required main vessel type
- Required support vessel type
- Spare stock initial
- Spare stock minimum
- Spare wait time
- Mission organization time

**Planned maintenance input data:**
- Maintenance times
- Subsystem grouping
- Required crew
- Required main vessel type
- Required support vessel type

**Power Estimation**

**Reliability Modelling**

**Failure rate data (turbines and BoP)**

**Mean Time to Failure**

**Weather forecast**

**Unplanned maintenance downtime**

**Total downtime**

**Planned maintenance downtime**

**Cost Estimation**

**Lost production cost**

**Revenue Estimation**

**Plant Availability Estimation**

**Cost input data:**
- Material costs
- Vessel costs
- Crew costs
ROMEO to date

WP8

Outputs
- Availability
- Downtime Breakdown
- Energy produced

- Revenue
- Cost Breakdown
  - Direct costs
  - Indirect costs

<table>
<thead>
<tr>
<th>Availability (%)</th>
<th>Energy Production (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>94.49</td>
<td>246,852</td>
</tr>
</tbody>
</table>
Summary

What makes ROMEO unique?

❖ Its completeness due to…

• The holistic study of failure development and degradation at both component and structural level
• The development of innovative solutions for failure diagnosis and prognosis and SHM filling an existing gap in both the industry and the academia
• Their integration in a flexible interoperable IoT platform feeding an Information Management System
• Their consideration for maintenance-related decision-making processes
• The demonstration and validation at full scale in three different real projects
• The stochastic assessment of the economic gain in terms of OPEX & LCoE reduction from real cases
Summary

**Main results so far...**

- FMECA workshops identifying critical failure modes both for WTG and substructure
- Physical models developed for specific failures on main turbine components
- Initial Data sets for data driven models prepared
- ICT architectures for the 3 demonstrators designed
- Backbone of O&M information platform developed
- Review of existing life cycle costing and O&M tools performed
Moving forward…

- Continue developing physical and data driven models
- Updating of FEM and benchmarking of low cost monitoring techniques
- Final report on best practice guidelines for future wind farm structural condition
- Development of Cloud environment and connections including O&M platform
- Testing of models and tools
- Development of Integrated Lifecycle assessment tool
What are the objectives?
The Project phases
Work description & packages
The progress: ROMEO to date
Summary & Future steps
Go raibh maith agat!

Wind Energy Science Conference - 18th June 2019
University College Cork, Cork

Elena González (elena.gonzalez.ext@siemensgamesa.com)
Take part in ROMEO Project and give us your opinion here

www.romeoproject.eu

Follow us on Twitter @RomeoProjectEU #RomeoProject