ROMEO Project

RELIABLE OM DECISIONS TOOLS AND STRATEGIES FOR HIGH LCOE REDUCTION ON OFFSHORE WIND

Sofia Koukoura
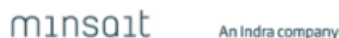
ScottishPower Renewables (Iberdrola Renewables)

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ROMEO

Consortium

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Adwen

bachmann.

LAULAGUN bearings

University of Strathclyde Glasgow

eDF

SIEMENS Gamesa RENEWABLE ENERGY

RAMBOLL
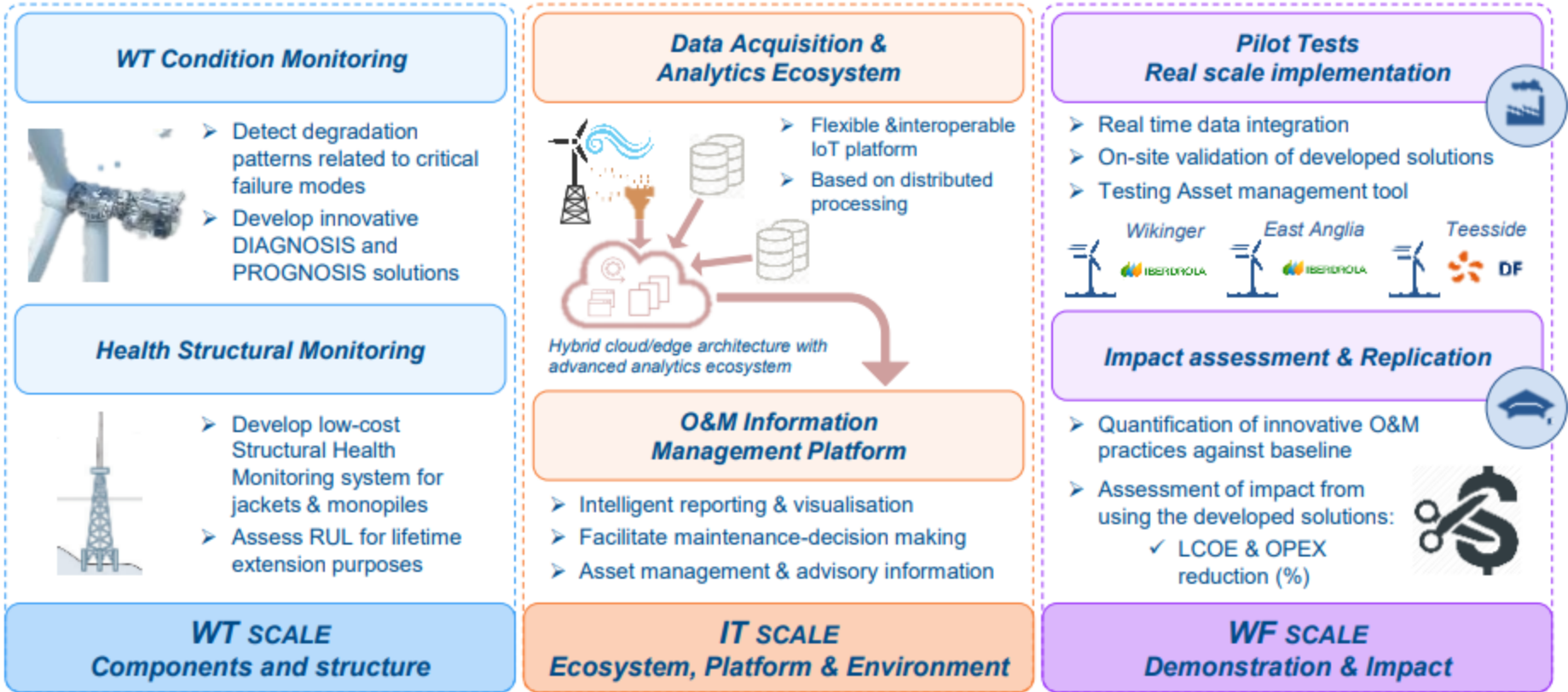
IBM Research | Zurich

UPTIME ENGINEERING

zabala INNOVATION

minsait An Indra company

- OEMs
- Utilities
- IT
- AI
- Academia
- Component manufacturer
- Condition monitoring
- Service providers
- Innovation consulting

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ROMEO Project Overview

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

Hybrid cloud/edge architecture with advanced analytics ecosystem

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

Wikinger IBERDROLA
East Anglia IBERDROLA
Teesside DF

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

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WP1: Failure Mode Effect and Criticality Analysis

- Important to **prioritize** systems for which condition monitoring would generate **highest value** and to understand the **parameters that need to be monitored** by a specific system from failure cause to failure mode.

- Monitoring objectives should be rooted in organisational strategic plans.
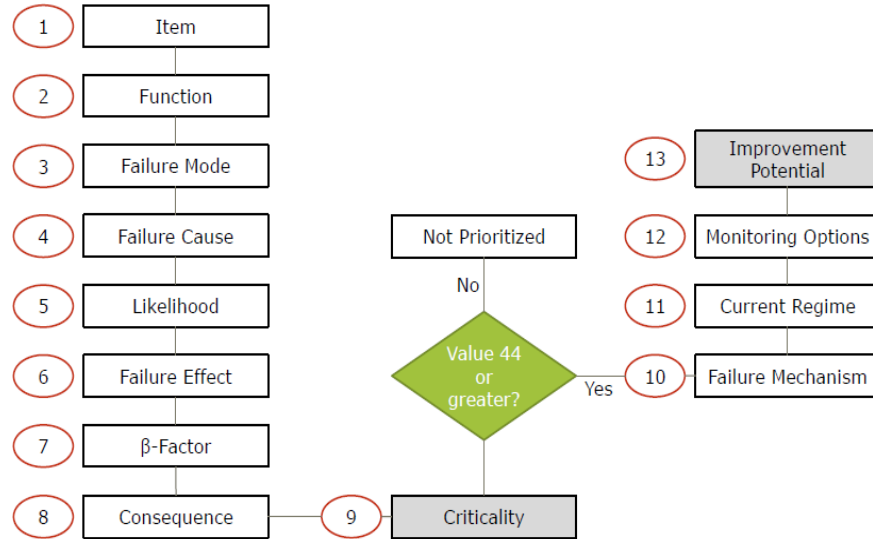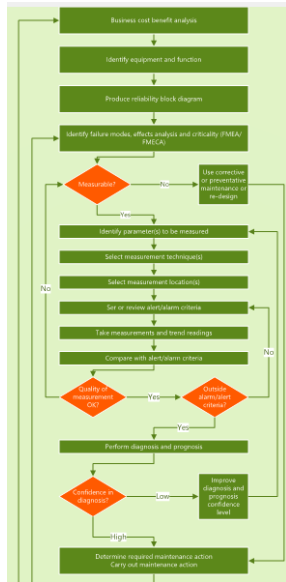
.[ISO17359]

WP2: New Monitoring technologies

- Development of new tailored monitoring solutions for specific failure modes.
- Test bench: Failure modes can be generated while the diagnosis system is being tailored
  - Proper sensors, configuration, data analysis.

Main Bearing & Gearbox

- Damage classification techniques
- Unbalance detection using vibration sensors
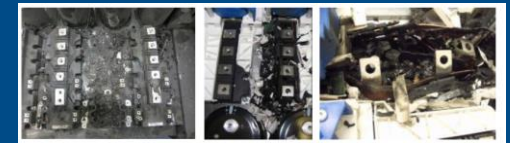- RMS Hardware Vibration Calculation
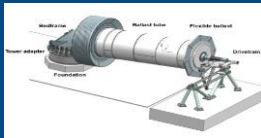
Blade Bearing

- Development of CMS for blade bearings : low failure rates but high criticality
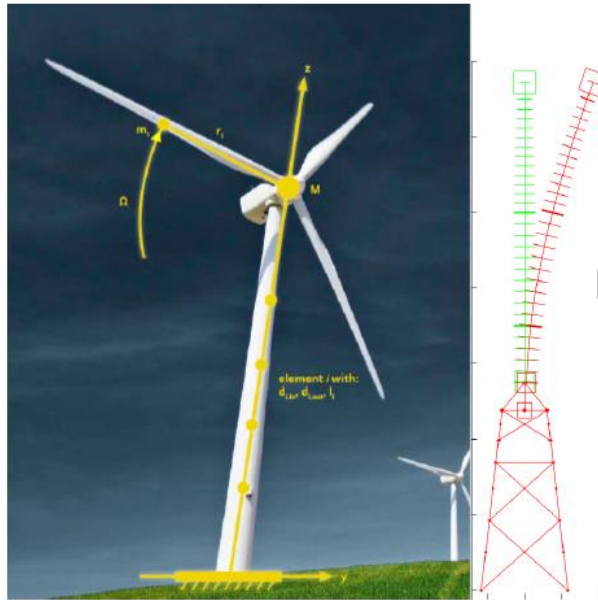

Electrical Drive Train

- Tests running @ EDF Electrical Lab generator ,transformer , capacitor)
- Bring components closer to end of life and mimic their failure

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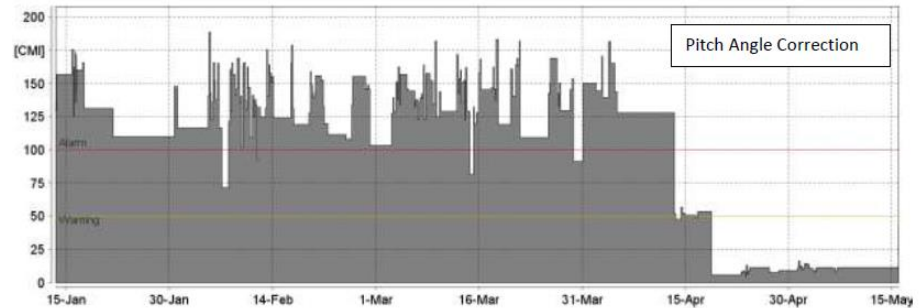
WP2: Online Unbalance Detection

Tower FE
(Stiffness and Inertia)

2D Acceleration
Rotor Speed
Rotor Angle (opt)

CMS

Acceleration
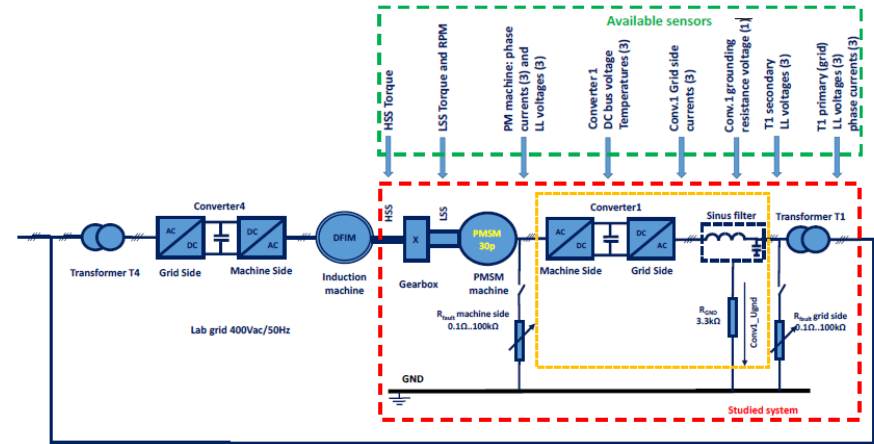Unbalance
Phase

bachmann.

*Aerodynamic unbalance example from pilot wind farm (CMI – normalised condition monitoring index, 100 equals alarm threshold)*

WP2: Electrical Drive Train

Reversible test bench;

- permanent magnet synchronous machine
- doubly fed induction machine

Available sensors: HSS Torque | LSS Torque and RPM | PM machine: phase currents (3) and LL voltages (3) | Converter1 DC bus voltage Temperatures (3) | Conv.1 Grid side currents (3) | Conv.1 grounding resistance voltage (1) | T1 secondary LL voltages (3) | T1 primary (grid) LL voltages (3) phase currents (3)

Transformer T4 | Grid Side | Machine Side | DFIM | Induction machine | Gearbox | PMSM machine | Converter4 | Converter1 | Machine Side | Grid Side | Sinus filter | Transformer T1

HSS | LSS | PMSM 30p | X

Lab grid 400Vac/50Hz

R_{fault} machine side 0.1Ω...100kΩ | R_{GND} 3.3kΩ | Conv1_Ugnd | R_{fault} grid side 0.1Ω...100kΩ

GND | Studied system

No Article	Name	Quantity
1	Plaque ENR Bench	1
2	DBF	1
4	Fitting plates DBF	4
5	Chair DBF	2
6	Fitting plates PMSG	4
7	Chair PMSG	2
9	HBM T40B 1kN	1
10	Chair HBM T40B 1kN	1
11	HBM T40B 10kN	1
12	Gearbox BONFIGLIOLI HDP 70	1
13	Chair BONFIGLIOLI	1
14	Coupling HBM T40B 1kN DBF	1
15	Coupling HBM T40B 1kN GB	1
16	Coupling HBM T40B 10kN GB	1
17	Coupling HBM T40B 10kN PMSG	1
18	Chair HBM T40B (10kN)	1
19	PMSG	1

EDF LAB PARIS SACLAY - DEPARTEMENT ERMES - T6B - BANC ENR

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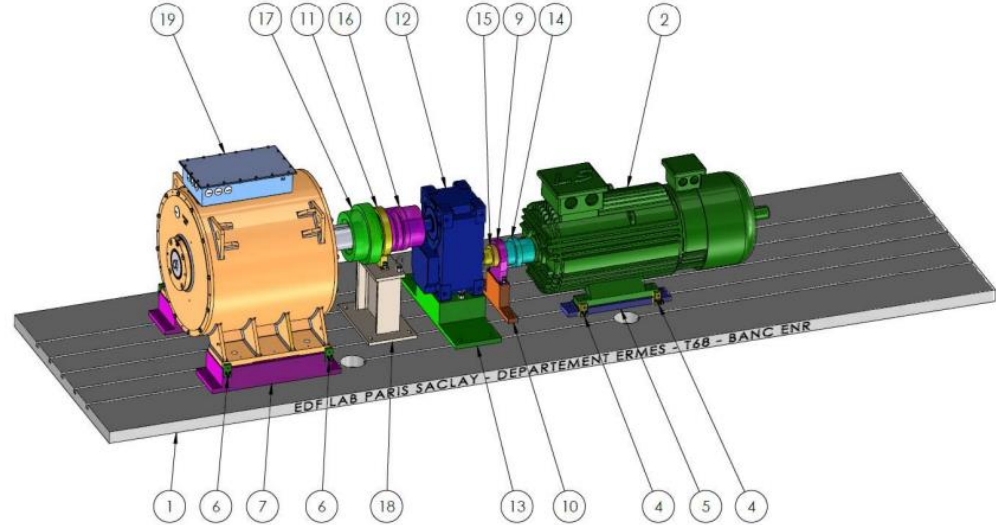
WP3: Physical and Machine Learning Models

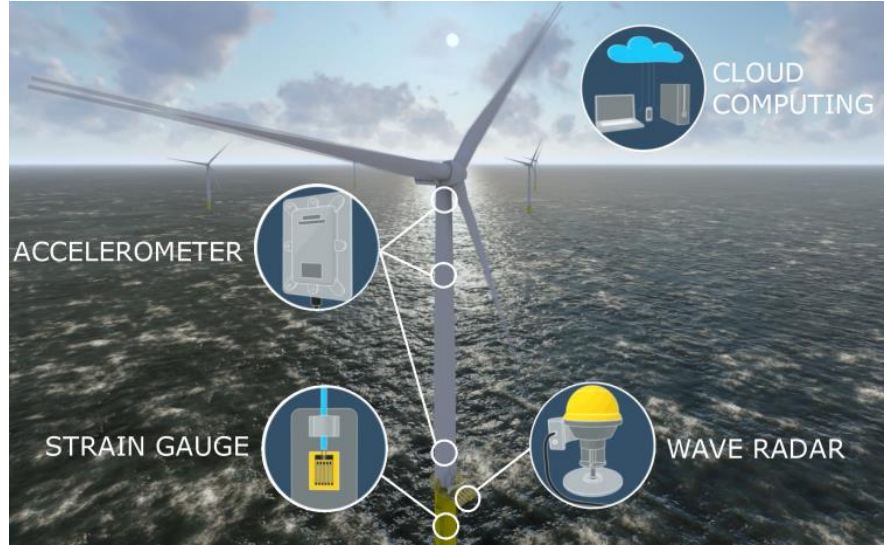| Module	Description
1	**Gearbox**, Sliding Bearings Wear/Blockage
2	**Converter**, DC link Capacitor Degradation
3	**Converter**, IGCT failure
4	**Generator**, Rotor Demagnetization
5	**Generator**, loss of insulation in the stator winding
6	**Blade Bearing**, fatigue and wear of raceways
7	**Blade Bearing**, loss of structural integrity
8	**Gearbox**, cracks in gears
9	**Gearbox bearings**, wear of raceways and rollers
10	**Main Bearing**, fatigue and wear of raceways
11	**Main Bearing**, fatigue and wear of rollers
12	**Main Transformer**, loss of insulation in the winding
13	**Main Transformer**, compromised structural integrity

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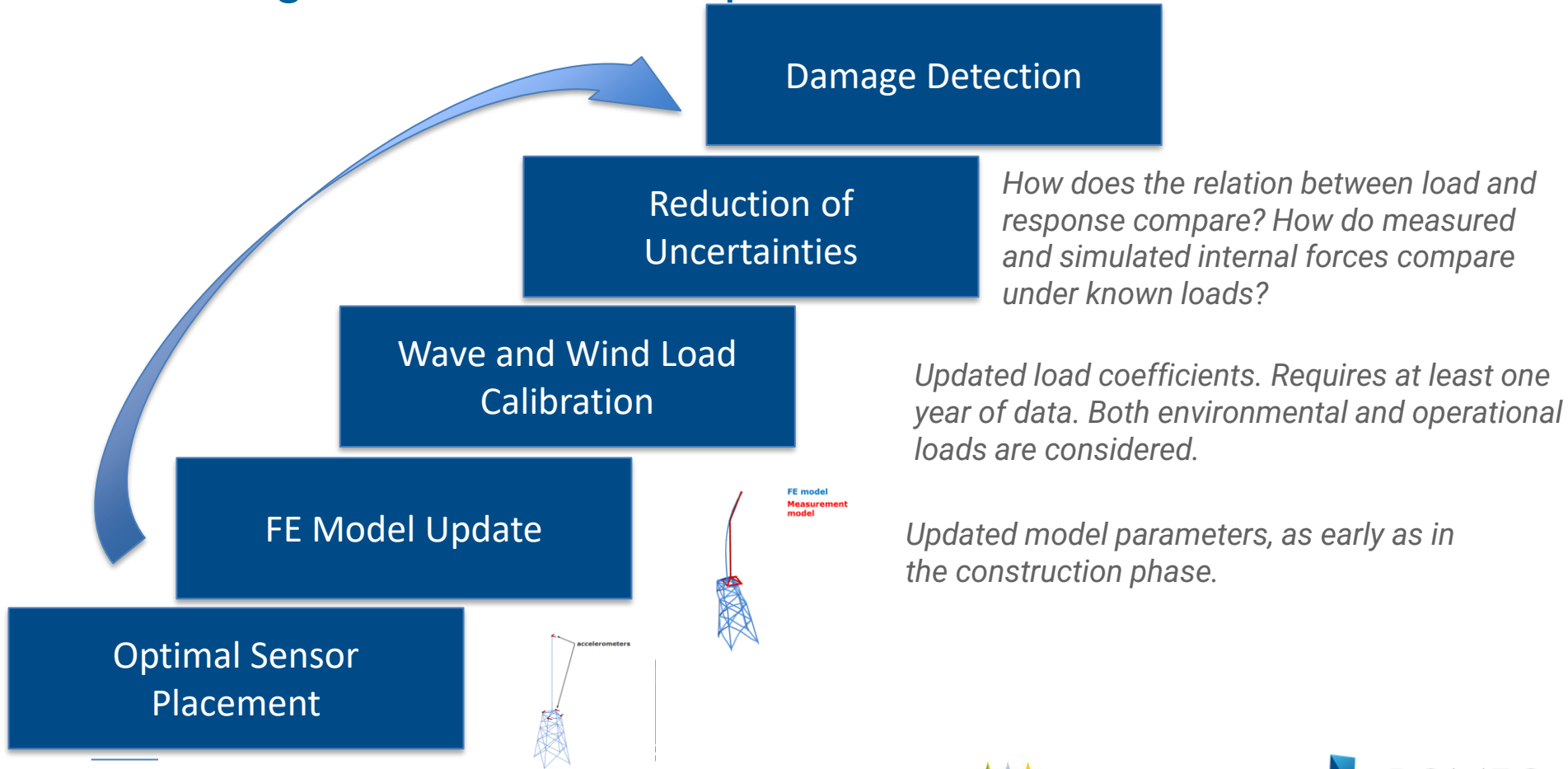# WP4: Digital Twins for Support Structures

Motivation:

- Measurements show deviations in structural dynamics between installed WTG and their corresponding FE model.
- Design process & assumptions are governed by certification standards.
- Timeline of projects does not allow for thorough site Investigations.

Targets:

- Reduce offshore work time
- Optimise Maintenance
- Reduce cost of consequence
- Improve asset availability
- Increase safety

WP4: Digital Twin Roadmap for Foundations

Damage Detection

Reduction of Uncertainties

How does the relation between load and response compare? How do measured and simulated internal forces compare under known loads?

Wave and Wind Load Calibration

Updated load coefficients. Requires at least one year of data. Both environmental and operational loads are considered.

FE Model Update

FE model
Measurement model

Updated model parameters, as early as in the construction phase.

Optimal Sensor Placement

accelerometers

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WP5: Data Acquisition

Real Time Systems

SCADA Connector applications integrated with the real-time operation systems for acquiring all the Wind farm monitoring data

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Edge Computing

Traditional IoT challenges:

- Volume problem of information
- Latency problem
- Security and privacy
- Strain on core/pi systems vs more data needed

Historical Data

Available to be uploaded on the Cloud through secure multiprotocol APIs

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ROMEO Project components

iSPEED
Real Time Data Integration Platform
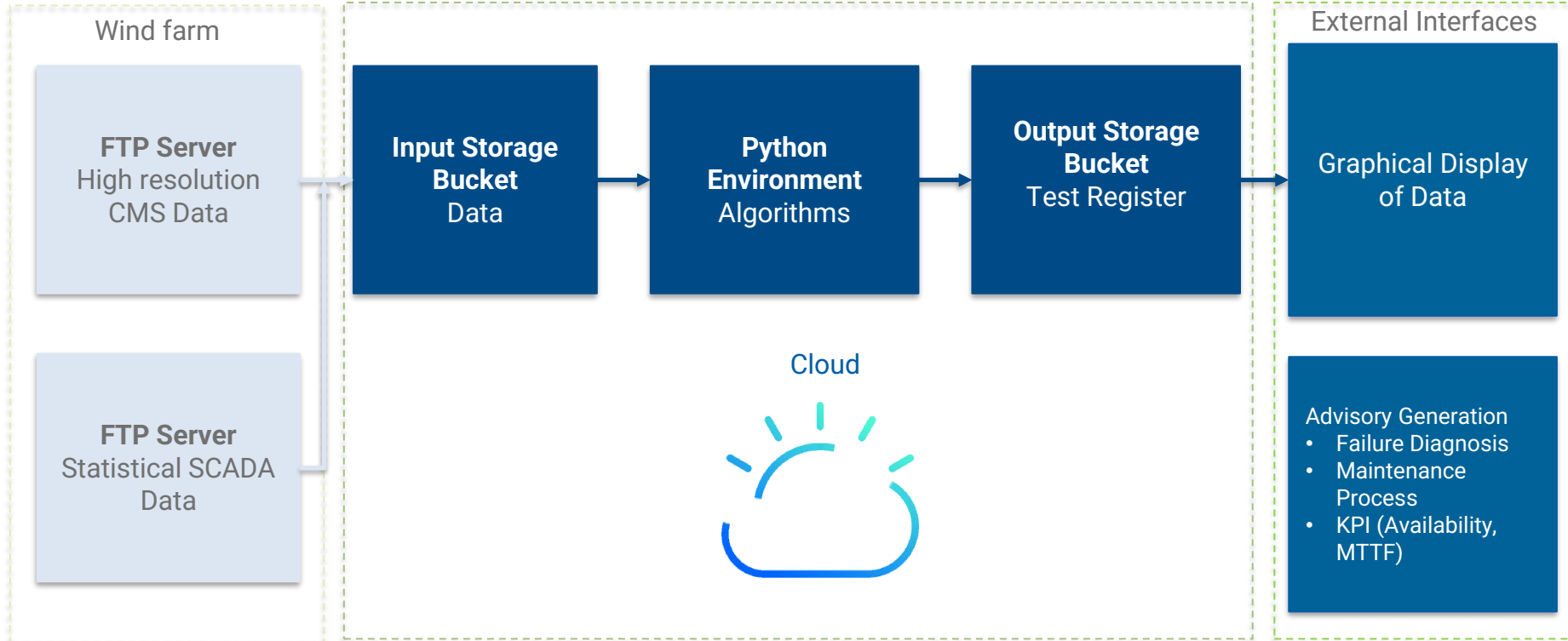**Babel connector**
SCADA Data acquisition

Industrial Node#1
SCADA Data acquisition & Edge Computing

**IBM ingest data APIs**
CSV, json, text files, SQL ...

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WP5: Data Integration

Wind farm

FTP Server
High resolution CMS Data

FTP Server
Statistical SCADA Data

Cloud

Input Storage Bucket
Data

Python Environment
Algorithms

Output Storage Bucket
Test Register

External Interfaces

Graphical Display of Data

Advisory Generation
- Failure Diagnosis
- Maintenance Process
- KPI (Availability, MTTF)

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WP6: Operation and Maintenance Management Platform

- Integration of multiple data sources
- Analysis and combination of information
- Centralized O&M Platform for access by multiple stakeholders
- Support of maintenance process
- Reporting and communication
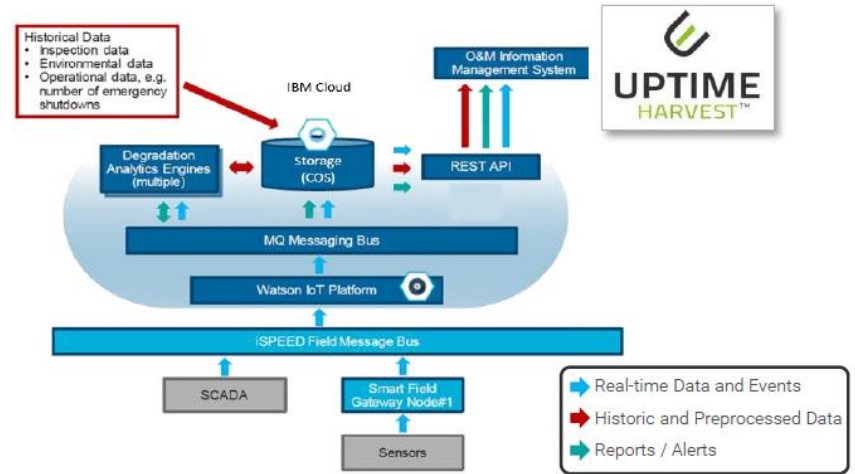
Summary

- 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.

- The integration in a flexible interoperable IoT platform feeding an Information Management System.

- 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.

Thank you for your attention!

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