Integrated Condition Monitoring for Wind Turbines – The NIMO System

J Gabriel, ISQ R&D Division

Emerging Renewable and Alternative Energy Technologies

International Workshop on Environment and Alternative Energy

17th November 2011

ISQ Fact Sheet

- 1,000 + 500 employees
- Consolidated turnover in excess of € 90 M
- 18 subsidiaries worldwide
- 20 aggregated SME
- The biggest technical private non profit organization in Portugal

R&D Fact Sheet

- Annual R&D expenditure of € 4 M
- Average 56 on-going projects
- Since 1985

  + 420 projects

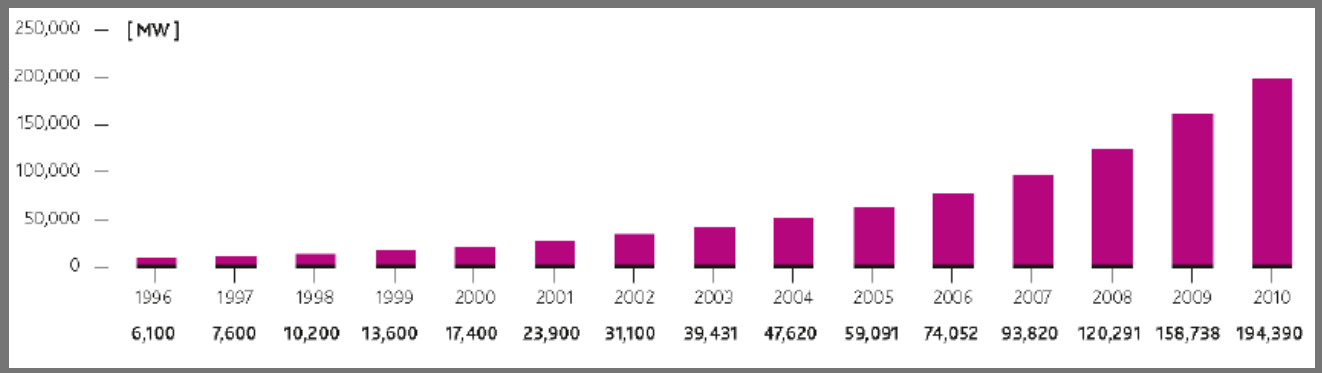
  + 1, 200 international partners

  + 30 countries
- International and national recognition

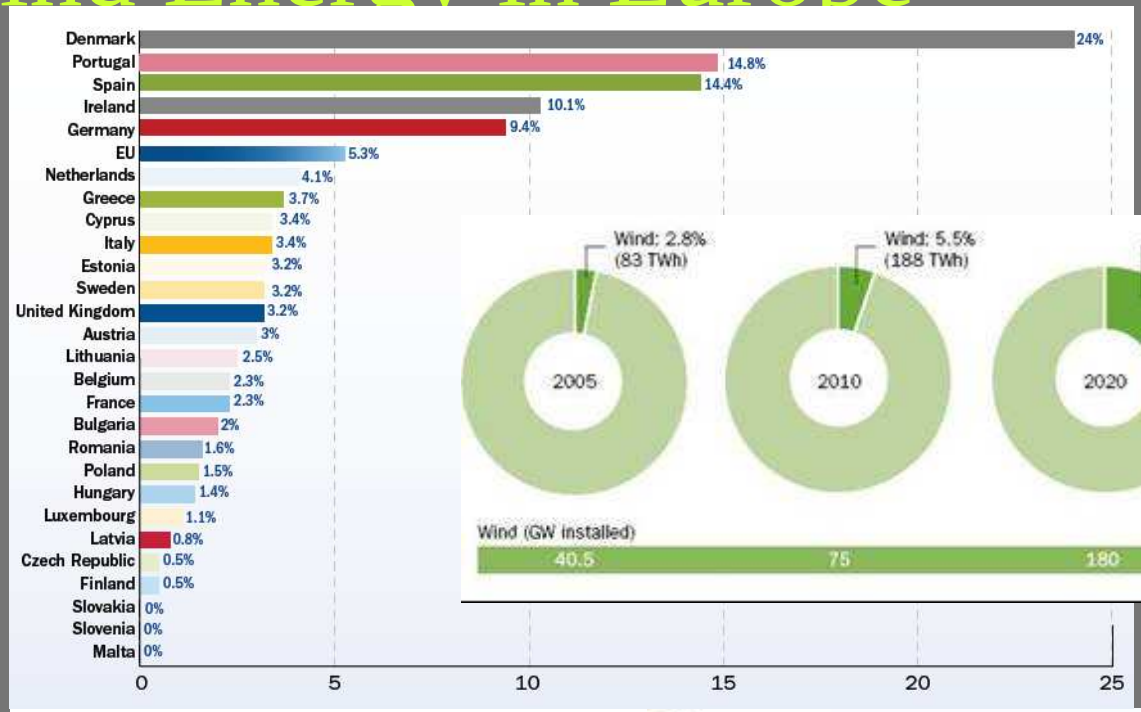
Where we are

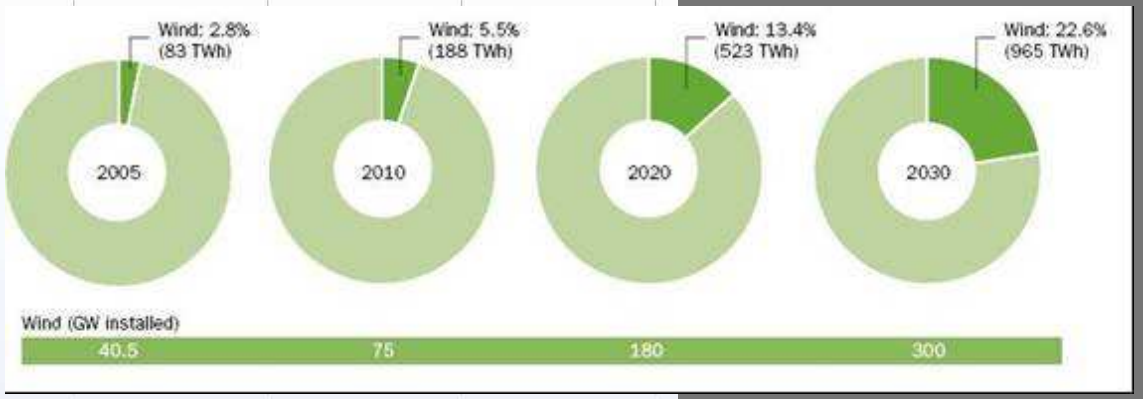
Wind power – A global energy player

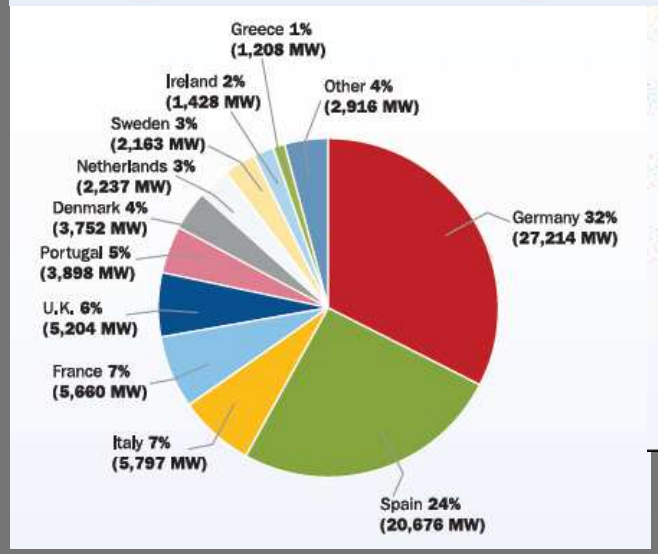
- Wind energy is currently the most developed of a number of renewable energy technologies, with several thousands of wind turbines either already operating or being planned for construction across Europe
- Cumulative global capacity has already exceeded 200GW. More than 40% installed in EU

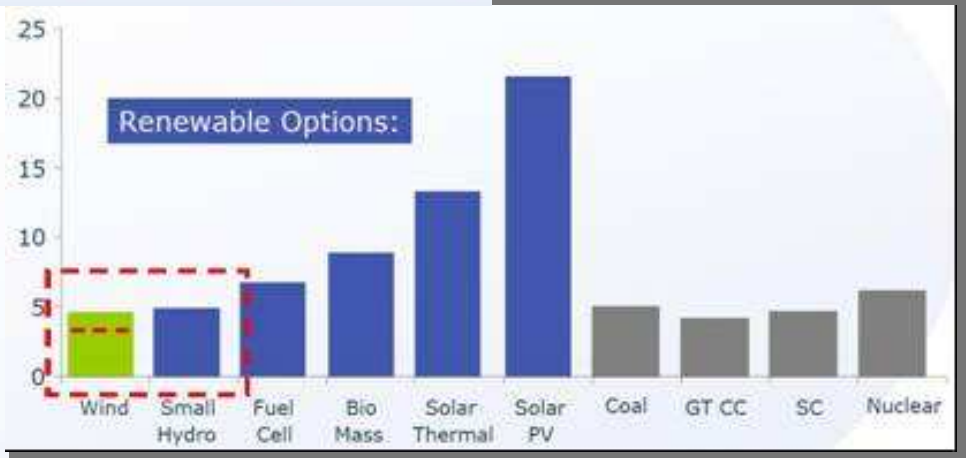


Wind Energy in Europe







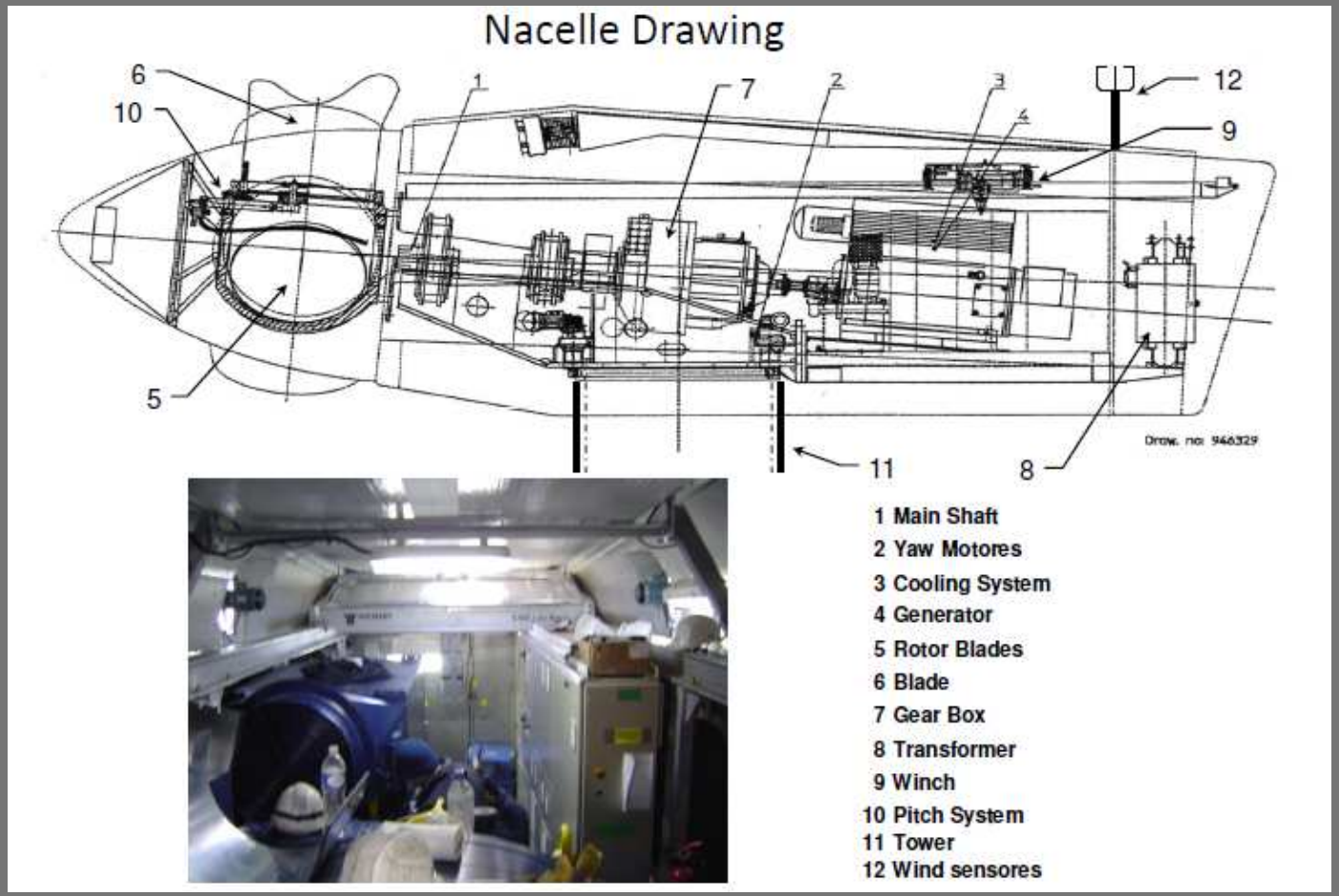


Main features of a typical turbine

Main Features

Rotor diameter:	83 m
Tower height:	78 m
Cut in wind speed:	4,0 m/s
Wind speed for nominal power:	16 m/s
Cut out wind speed:	25 m/s

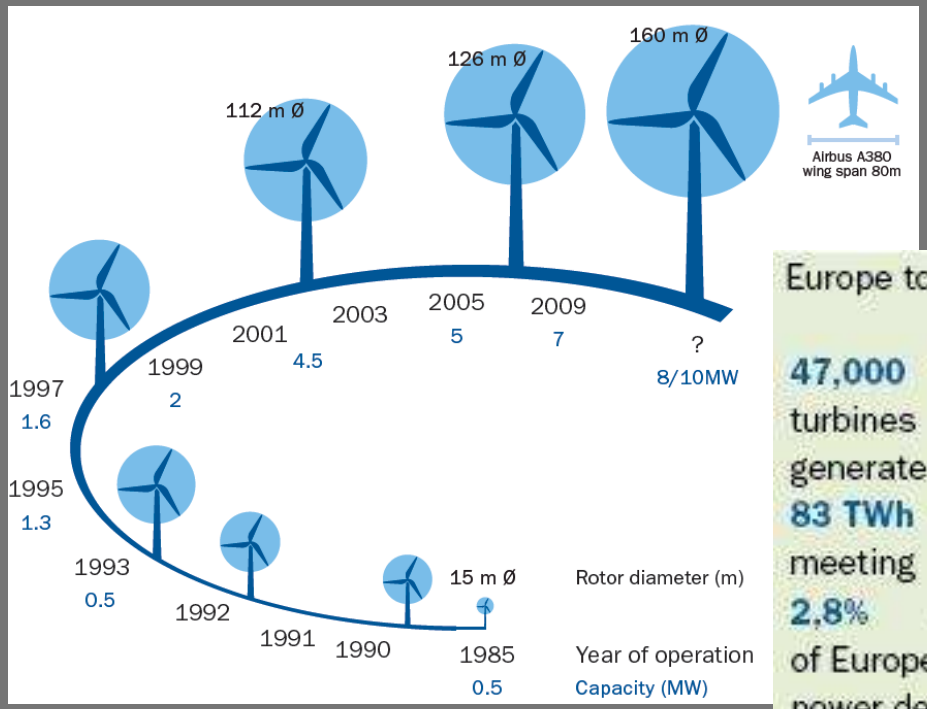
Nacelle features

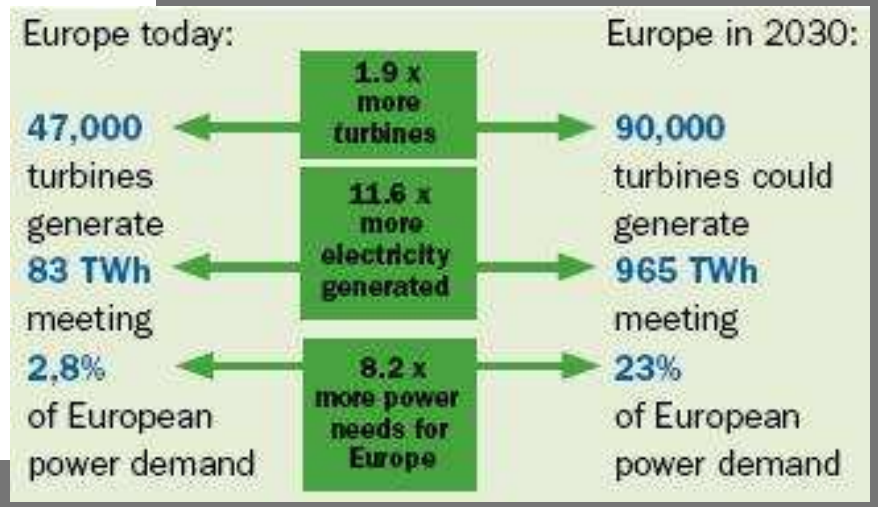


Current state-of-the-art wind turbines

- Wind turbines can be deployed individually to power a single site or installation, but are most commonly grouped together as wind farms to provide power to the electricity grid
- The energy output from wind turbines has increased dramatically over the past thirty years from 50 kW to 6 MW, while 8-12 MW turbines are in the design stage
- Tower height and rotor diameter of turbines have doubled leading to more complex construction, maintenance and inspection procedures

Size of wind turbines growing





Source: EWEA, 2008

Maintenance and repair

- Costs associated with maintenance can exceed 20% for onshore and 30% for offshore wind farms of the overall energy generation costs
- A significant % of the maintenance cost can be associated with unexpected failures of wind turbine components (including structural components, i.e. blade and tower; rotating components, i.e. gearbox or drive train, yaw, and generator; and braking system) leading to unscheduled corrective maintenance actions

Increasing Size considerations

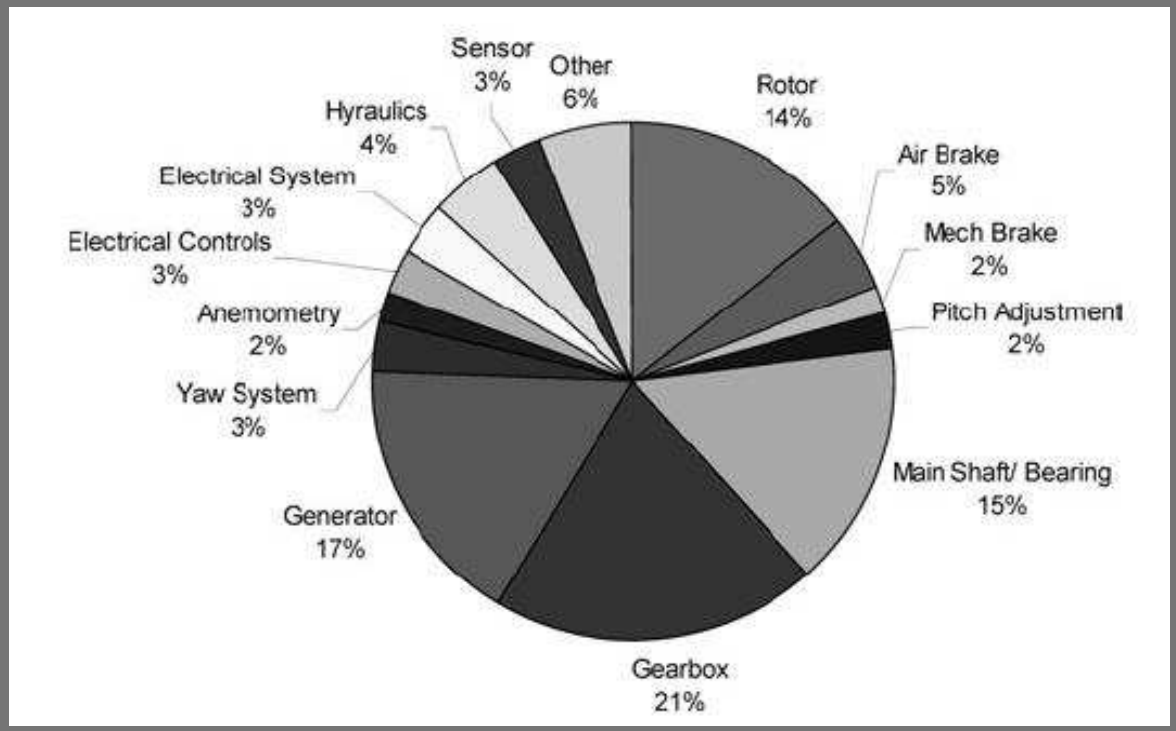
- The continuous growth in wind turbine size and numbers has led to increased demands in inspection and maintenance
- The fact that wind farms are commonly located at remote sites with poor accessibility or offshore means it is absolutely necessary to practically eliminate the need for corrective maintenance through evolution to preventive maintenance activities

Wind turbine failures

- The wind energy industry has experienced relatively high levels of failure rates from its inception
- Failure rates still remain high

Wind turbine downtime by mode of failure

- Reported by McMillan and Ault, 2008



Current structural inspection procedures

- Techniques commonly employed for the structural evaluation of wind turbine components include visual inspection, eddy current (EC) sensing and ultrasonics testing (UT)
- These techniques need to be performed manually and require highly experienced personnel to carry them out
- Radiography, shearography and thermography are also employed but only occasionally

Nacelle inspection and CM procedures

- Visual inspection
- Oil analysis
- Anemometry, output and RPM monitoring
- Temperature ambient and oil
- Vibration analysis is used less often and data is usually not released to operators by the wind turbine manufacturers
- Oil particle sensors more recently have been under consideration

Inspection Matrix

	Gearbox	Generator	Blade	Rotor	Bearing	Tower
Vibration	g[29], g[31], a[33], e[34], d[35], j[36], d[37], h[38] dhj[39], hd[77], e[80], j[86], j[91], jk[92], [101]		a[102], j[103]	e[33], e[81], a[82]	g[29], a[33], e[34], a[40], g[41], g[42] j[43], gj[44], e[80], j[87], j[89], k[97], j[103], j[104]	g[29]
Oil	d[47], a[72]	[105]			a[36], [49]	
Thermography	l[67]	l[67]				
Physical condition of materials					[41], [42]	
Strain			[68], [106]	[107]		
Acoustic	a[72], j[91]		a[1], [68], [108], a[116], a[117]	j[109]	a[56], gh[63], d[78], [110], a[111]	
Ultrasonic			j[59], [108], a[112], [113],			
Electrical effects		a[71]				
Shock Pulse					gh[63], a[65]	
Process parameters		a[66]	a[67]			
Visual inspection			[114]			
Performance monitoring	e[115]	a[66], d[69]	[68]		eg[115]	

The NIMO project

- To develop and demonstrate a novel integrated condition monitoring system for wind turbines
- Project officially entered 'Active' status from 1st October 2009
- Consortium consists of 15 partners around Europe with total project budget approximately 6M Euros
- Project managed jointly by TWI and UOB
- First stage of demonstration to be concluded by 2012 at CRES wind farm in Lavreotiki, Greece

Lavreotiki testing facilities

SE Attica, Greece

The NIMO Consortium

Participant No.	Participant Organisation Name	Participant Organisation Short Name	Country
1	TWI Ltd.	TWI	UK
2	Alfa Products and Technologies	APT	Belgium
3	Lambdatest Ltd.	Lambda	UK
4	Technology and Quality Control Centre M. Kotouzas Inc.	TQCC	Greece
5	TSC Inspection Systems Ltd.	TSC	UK
6	ACCIONA ENERGIA S.A.	ACCIONA	Spain
7	Envirocoustics ABEE	ENVAC	Greece
8	A. Silva Matos Energia	ASM	Portugal
9	Feldman Enterprises Ltd.	FELDMAN	Cyprus
10	Novas Energias do Ocidente S.A.	NEO	Spain
11	TERNA S.A.	TERNA	Greece
12	Centre for Renewable Energy Sources	CRES	Greece
13	The University of Birmingham	UOB	UK
14	Instituto de Soldadura e Qualidade	ISQ	Portugal
15	University of Castilla-La Mancha	UCLM	Spain

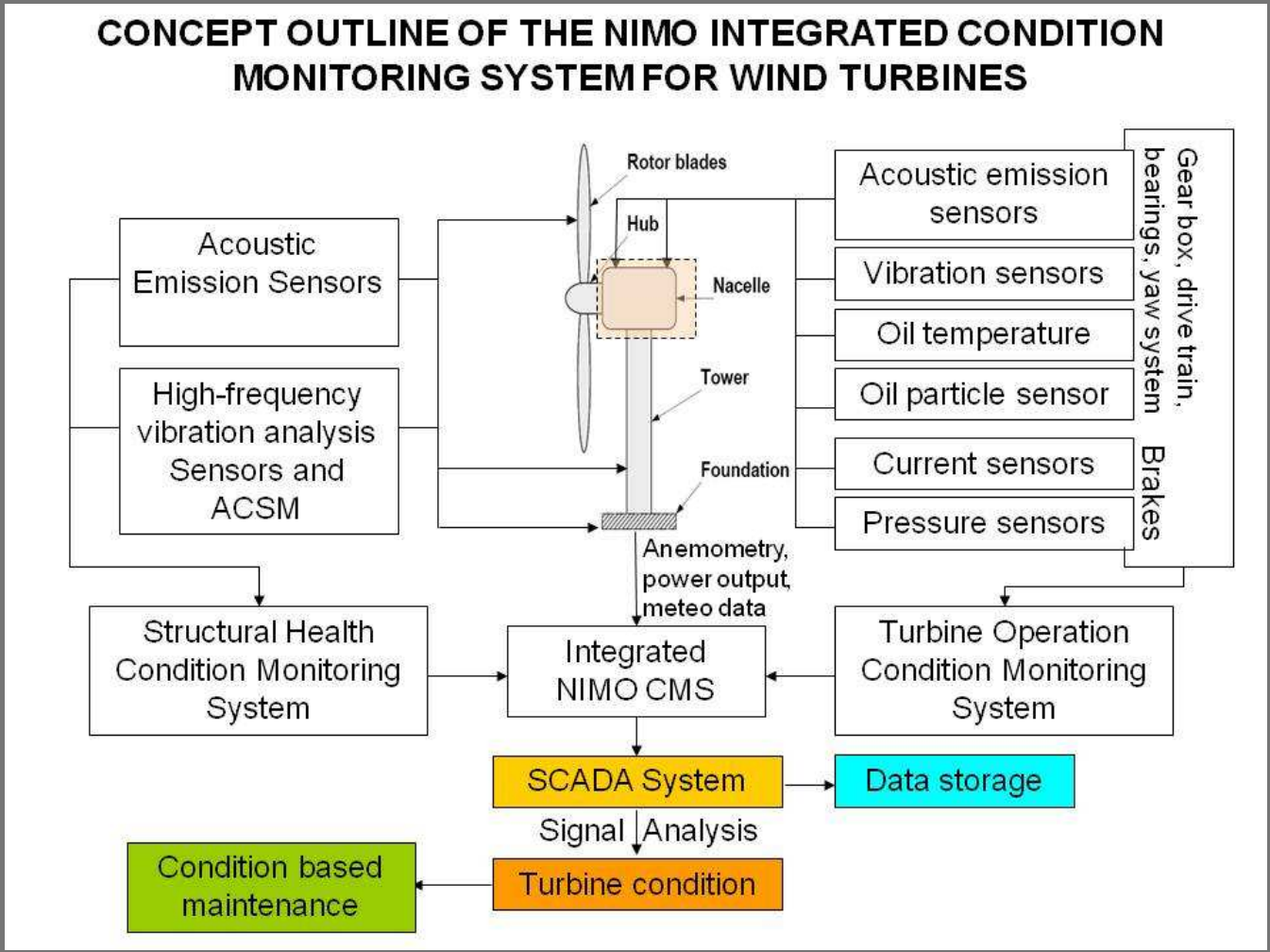
Project objectives

- To reduce the number of catastrophic failures and minimise the need for corrective maintenance by developing and successfully implementing an integrated condition monitoring system for the continuous evaluation of wind turbines
- Advance existing state-of-the-art condition monitoring technology used in wind turbines
- Increase the competitiveness of wind energy in comparison to other power generation technologies through useful and measurable innovation

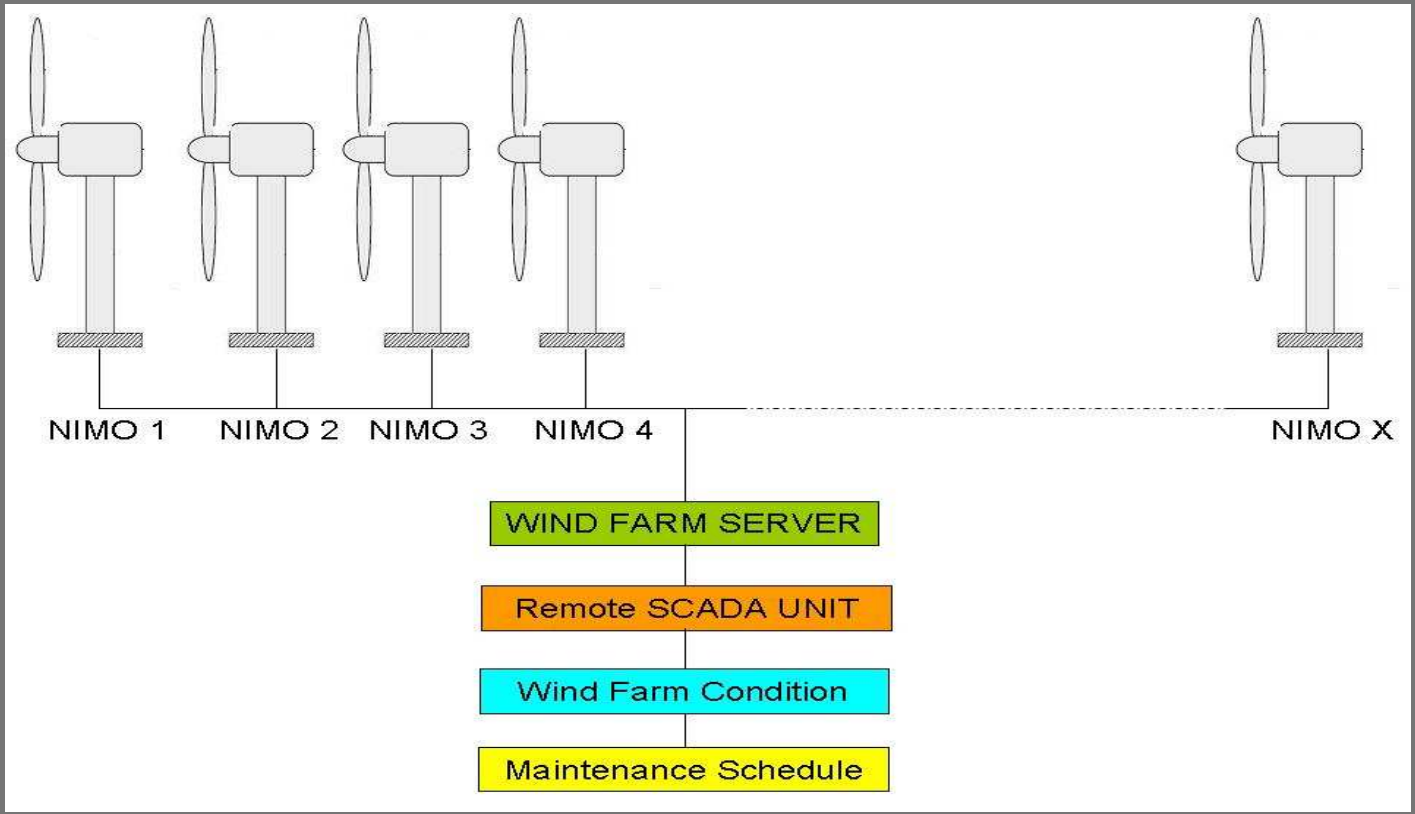
Project objectives (continued)

- To demonstrate the new technology under actual operational conditions and on state-of-the-art wind turbines
- Establish strong links among participating partners and where appropriate with key organisations outside the consortium
- Lead to a valid commercial solution following the end of the project

NIMO integrated system



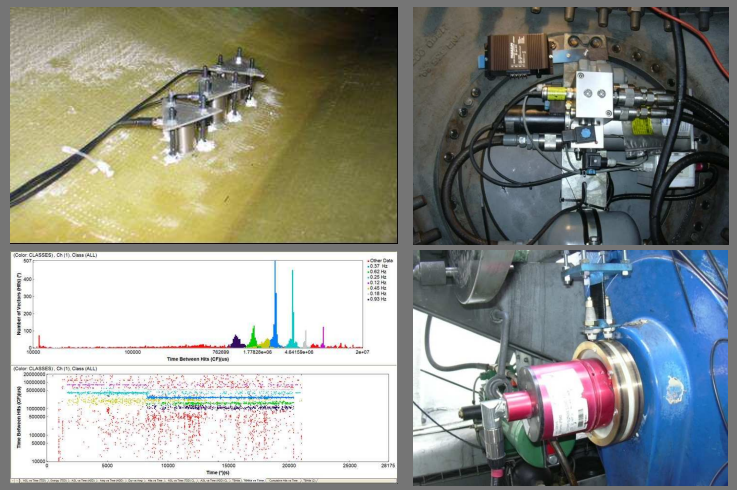
NIMO Application in the Field



Prototypes developed

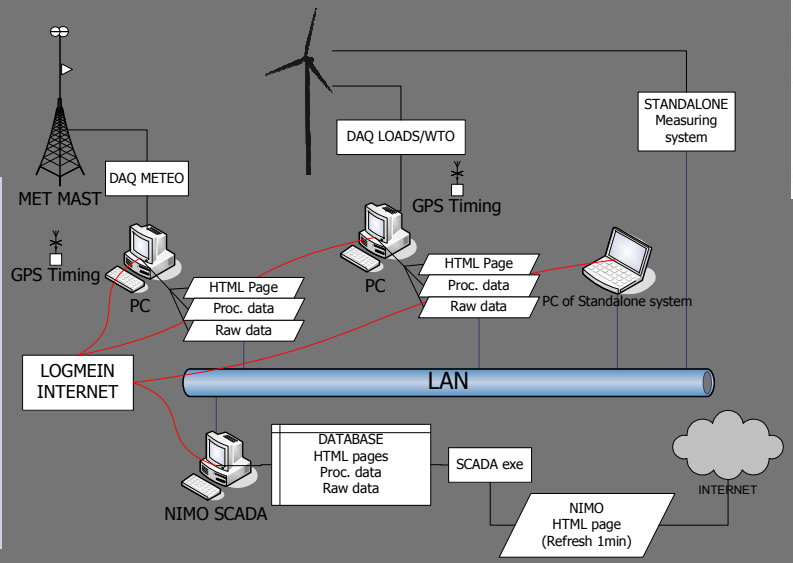
- For structural CM of tower high-frequency vibration analysis and ACSM prototypes
- For structural CM of foundation vibration analysis prototype
- For structural CM of blades AE prototype
- For operational CM current and pressure sensing prototype
- For gearbox and rotating components vibration and AE prototype
- Commercial oil analysis sensors acquired from external provider
- Central intelligent data logger developed

Structural AE module installation

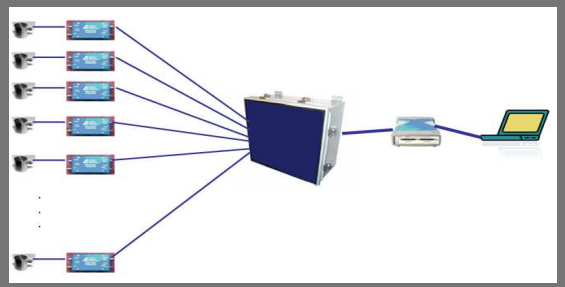


HF vibration module for structural monitoring

NIMO Data Flow

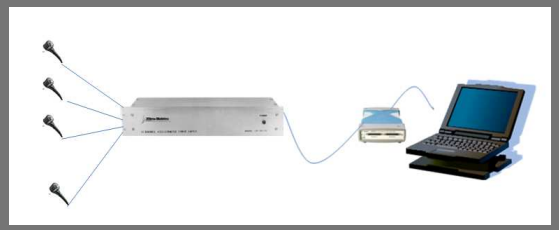


AE module for rotating components



Alternating Current Stress Management module

Vibration module for rotating components



Non Technical Challenges

- IP Management
  - Background and foreground
  - Joint ownership
  - Licensing to other beneficiaries
- Opportunity and Timing
  - End of warranty period
  - New and installed turbines

Non Technical Challenges (continued)

- Market and system configuration
  - Manufacturers, operators and maintenance subcontractors
  - One size fits all?
  - Existing sensoring
- Business model
  - Equipment and service providing
  - ESCOs proof of concept

Conclusions

- NIMO integrates a number of CM techniques in order to evaluate the actual operational and structural condition of industrial-scale wind turbines
- Overall cost of the system is expected to be reasonable, increasing the possibilities of widespread commercialisation
- Demonstration of the integrated system will provide a clear picture of its capabilities
- Non Technical challenges will determine time-to-market and scope of exploitation of results

Acknowledgements

- The European Commission for the financial support of this project
- The NIMO consortium partners for their contributions
- Dr Christian Nath of Germanischer Lloyd and Mr Matthieu Crayé of the European Commission (DG Energy) for their advice

Thank you for listening

For more information please contact jsgabriel@isq.pt
or visit the project's website at www.nimoproject.eu