Logistic Efficiencies And Naval architecture for Wind Installations with Novel Developments

Project acronym: **LEANWIND**
Grant agreement nº 614020
Collaborative project
Start date: 01st December 2013
Duration: 4 years

Condition Monitoring software and RAMS tool kit for wind turbines

Work Package 4 - Deliverable 4.4

Lead Beneficiary: PLOCAN (19)
Due date: 31st July 2016
Delivery date: 4th August 2016
Dissemination level: CO (Confidential)

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No.614020.

Disclaimer

Document Information

Version	Date	Description			
			Prepared by	**Reviewed by**	**Approved by**
V1	08/07/2016	First version	Blas J. Galván (ULPGC)	Marcos Rodríguez Camacho (ULPGC)	J.J. Hernández Brito (PLOCAN)
V2	19/07/2016	1st Peer reviewed version		Pantelis Anaxagorou (NTUA)	
V3	25/07/2016	2nd Peer reviewed version		Fiona Devoy McAuliffe (UCC)	
V4	01/08/2016	Version with comments and corrections from peer reviewers	Blas J. Galván (ULPGC)	Marcos Rodríguez Camacho (ULPGC)	
V5	04/08/2016	Final version reviewed by PM-T		Jan Arthur Norbeck (MRTK)	Jan Arthur Norbeck (MRTK)

Author(s) information (alphabetical):	
Name	**Organisation**
Blas J. Galván González	ULPGC

José Joaquín Hernández Brito	PLOCAN

Acknowledgements/Contributions:	
Name	**Organisation**
Juan Pedro Ramos Ponce	PLOCAN
Francisco Rodriguez	ULPGC
Marcos Rodríguez Camacho	ULPGC

Definitions

Acronym	Definition
AA	Acoustic Analysis
ANFIS	Artificial Neuro Fuzzy Inference System
ANN	Artificial Neural Network
AR	Autoregressive model
ARIMA	Autoregressive Integral Moving Average model
ARMA	Autoregressive Moving Average model
BSD	Berkeley Software Distribution
CM	Condition Monitoring
CMS	Condition Monitoring System
CSV	Comma-Separated Values, data file
DE	Drive End
DTO	Data Transfer Object
GS	Genetic Search
HTTP	Hypertext Transfer Protocol
ICA	Independent Component Analysis
IDPS	Integrated Diagnosis and Prognosis System
JSON	JavaScript Object Notation
K-NN	K-Nearest Neighbours
KS	Knowledge System
MIT	Massachusetts Institute of Technology
NARX	Nonlinear Autoregressive model with exogenous inputs
NBM	Normal Behaviour Model
NDE	Non Drive End
NSET	Nonlinear State Estimate Technique
OA	Oil Analysis
OS	Operating System
PCA	Principal Component Analysis
PPA	Parameter Performance Analysis
PSO	Particle Swarm Optimization
RAMS	Reliability, Availability, Maintainability and Safety
RMSE	Root Mean Square Error
ROA	Resource Oriented Architecture
ROC	Receiver Operating Characteristic
RUL	Remaining Useful Life
SA	Structural Analysis
SCADA	Supervisory Control And Data Acquisition
SISO	Single Input - Single Output model

Acronym	Definition
SNR	Signal-to-Noise Ratio
SOM	Self-Organizing Maps
SQL	Structured Query Language (Programming language)
SVM	Support Vector Machines
TGA	Thermographic Analysis
TSA	Time Synchronous Averaging
TTF	Time To Failure
VA	Vibration Analysis
WT	Wind Turbine
WTCM	Wind Turbine Condition Monitoring

Executive Summary

The problem addressed in this document is the design, development and commissioning of an online system for condition monitoring and diagnosis/prognosis of faults in off shore wind turbines. The software developed must be flexible in order to facilitate its use by different wind farm operators with different exploitation policies and business concepts. Other desirable characteristics are the capacity to store private data sets and the capacity to modify over time some software pieces (scripts) to keep them updated. The current software comprises specific tools in order to make its use compatible to other software developed in the LEANWIND project.

Based on the current state of the art, two possible solutions were identified. The first was to develop a set of software pieces with the capacity to work in an internet based distributed computing environment. The second was to develop a web service, available online in one or more internet sites, which includes scripting capacities that will allow end users to improve the software over time.

After a complete state of the art analysis on Wind Turbine Diagnosis and Prognosis methodologies, International Standards and internet based programming tools, the option selected was to develop a web service with scripting and data management capacities. This option mixes the latest industry applicable methodologies of Fault Diagnostic and Prognostic, recommended by international standards, with the most updated advances in web services, putting together the best knowledge of the industry and the best digital technology in a unique and new software piece.

The result is a web service with the capacity to receive, store and analyse datasets coming from the offshore wind farm industry. The data sets must contain reliable information from sensors installed on wind turbines and/or in the SCADA system, but further refinement processes or other types of analysis (reliability analysis) can be performed by the web service. Once the data sets are ready for analysis, each user can select different software templates, provided by the web service, in order to directly analyse the data set or to modify the template to improve the results using the user's knowledge. The main results are Fault Diagnostics and Prognostics, but the scripting language also allows the user to obtain other results related to RAMS technologies. Typical diagnostics can be: "No Degradation patterns identified" and "Degradation pattern X identified with Y confidence level" (example: Alert: Vibration on bearing X is out of normal values, confidence level 65%). The most important prognostic result can be the Remaining Useful Life (RUL) (example: RUL for bearing X is 2 month using a predefined threshold for the selected feature).

The last stage when developing software is the quality control, so here a quality control has been performed on the developed web service. LEANWIND industrial partners will now have a tool available for online Fault Diagnostic and Prognostics for offshore wind turbines, as well as other RAMS calculations. Combined with work done in other LEANWIND tasks, it is possible to use such web service to solve different cases of interest for the industrial partners. Since the RUL and Fault Diagnostics are necessary as part of the information needed to set up O&M strategies, the results of this web service will be useful tool to optimize O&M operation for offshore WTs. A complete user's manual with examples and test cases will be provided with the web service.