FLOW Final Report

Project title : **DUWIND's far offshore wind farm design**
WP4: Availability-based design of offshore wind power stations.

1. Project Summary

The current offshore maintenance organization is still facing a significant amount of unplanned and corrective actions. It is clear that this should be shifted towards more pro-active preventive maintenance activities in the near future. In other words try to repair before a real failure occurs. The main objective of the project was to develop methods that will help to reduce corrective maintenance events. This leads to an increased availability of future far offshore wind turbines and wind farms. The project has investigated different approaches of data acquisition and monitoring as well as reliability practices. Also the use of the SCADA systems for determining abnormal conditions has been investigated.

A systematic approach for developing a more pro-active maintenance work plan starts with an inventory of current experiences. For such purpose it is necessary to acquire a variety of operational information at different offshore locations. Data and further information was obtained from several offshore wind farms in Belgium, Denmark, the UK and The Netherlands. This information was used to analyse existing downtime events. This did not only mean that each event had to be identified, but also that the reason for each downtime had to be investigated. Ideally this identification provides the "root cause" of a downtime. This means for example that identifying an overheated gearbox as "the cause" of downtime does not suffice, it should be narrowed down to root causes such as shortage of gearbox oil due to oil pump malfunctioning, wear in a bearing or extensive wear of one of the gearwheels, just to name a few.

After careful assessment of the data of these different offshore wind farms it turned out that root cause finding is virtually impossible in most cases. A structured uniform approach on reporting events with a proper and uniform taxonomy was not always present let alone a semi-automated and highly simplified data acquisition and analysis system. Even seemingly simple issues, like a proper and uniform taxonomy used over the different offshore wind farms was lacking. Since the development of more uniform taxonomies, service and maintenance reports and automated data analysis is beyond the scope and capacity of a single PhD research and it was decided to join forces in the IEA Task 33 on Reliability Data and Standardisation of Data Collection for Wind Turbine Reliability. However the target of the FLOW project was maintained: to find ways to move away from unexpected repair events towards a predictive repair strategy.

Because of the first disappointed experiences in accessing and analysing reliability and maintenance data from a variety of offshore wind farms the focus moved toward a single, more specific, yet representative, offshore wind farm design. For this ENECO's operational PAWP (Princess Amalia

Offshore Wind Park) was chosen and observed failure events over the past six years were identified, categorised and benchmarked against publicly available failure data. The conclusion was that the public data bases do give a realistic picture about the number of failures per subsystem. However narrowing this down to components and subcomponents turned out to be impossible, again due to a lack of consistent taxonomy and terminology.

As a part of the implementation of the knowledge obtained from the above analysis, a strategy optimisation for a future Dutch offshore wind farms with a typical size of 350 MW using current gearbox and bearing reliabilities was performed. The results show that increasing the unit size of the wind turbines is beneficial for the operational costs. Compared to the standard 3 to 4 MW currently used the cost related to the exchange of main components (such as blades, gearboxes and generators) can be reduced by around 20% if 8-10 MW machines show a similar maintenance demand as the current size of machines, assuming an optimal exchange strategy is implemented.

Such strategy is characterised by a reactive strategy during the first operational years (so repair/exchange on demand), but after a period of 5 to 10 years an batch wise strategy should be adopted with typically 2 to 3 campaigns per year. In other words: after the first 3-5 years of operation the production loss does not balance anymore the additional costs of mobilisation and large repair of each individual wind turbine big failure. This has to do, amongst others with the fact (based on historic public reliability data validated with a.o. PAWP confidential data) that in the first 3-5 years the failure frequencies are higher than in a remaining period of typically 10 years.

Tax. Level	Hierarchy IEAWT33	ISO 14224	RDS-PP Wind	Reliawind	NERC-GADS	Examples
1	Plant	Plant / Unit category	RDS-PP Conjoint designation, level 2	-		Wind power plant, PV-plant, Bio energy plant
2	System	Section / System	RDS-PP Function level 0	System	System	Wind Turbine, BOP, roads, Offshore Found.
		Equipment class / Unit				Similar equipment Rotating, Electrical, Mechanical
3	Sub-system	Sub-unit / Sub-system	RDS-PP Function level 1 AAA	Sub-System	System	Rotor system, drive train, generator systems
4	Assembly		RDS-PP Function level 1 AAA NN	Assembly	System / Component	Shaft system, speed conversion, brake system, blade, gearbox
5	Sub-Assembly	Maintainable item	RDS-PP Function level 2 AA NNN	Sub-Assembly	System / Component	Bearing assembly, hydraulic pump assembly
6	Part	Part	RDS-PP Product	Component		Bearing, planetary gear, pump motor, brake pads

Table1: Example of IEA Task33 taxonomy standardisation (draft version).
Several methods to define systems, subsystems and components in offshore wind farms exist. IEAWT33 aims to come up with a recommendation for standardization/harmonization of the currently most commonly used taxonomy systems used in wind energy such as RDS-PP, Reliawind and NERC-GADS.

Compared to the present state of the art in Offshore Wind Energy, an optimised O&M strategy can lead to ~ 6% reduction in the overall costs of maintenance. And since the maintenance costs are usually around 25-30% of the CoE, this would mean a reduction of ~2%. But also the increase of CAPEX (investment costs) needs to be taken account for retrieving more knowledge from SCADA systems, as well as the costs for a more (extensive) condition monitoring system need to be taken into account. These are estimated to be 1-2% of the wind turbine related part of the CAPEX, which then ends up with an estimated CoE reduction of 1.6±0.2%.