Grid Interconnected ***R***eliable ***O***ffshore Wind ***E***nergy Prediction Models

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Currently more than 20 offshore wind turbine (OWT) designs are being considered for deployment in high wind marine environments. However, specific reliability prediction models are not yet available. The present state of the OSW technology makes it increasingly difficult for developers and investors to evaluate prospective reliability of various technologies.

The objective of this research is to develop a methodology and to model individual OWT failure rates for current generic designs, and to predict root cause of failures through physics of failure models. Our work will allow the State of Maryland to compare the relative reliabilities of various types of turbines. The physics of failure approach, coupled with reliability predictive models will help advance the entire industry by leading to new robust designs of OWTs. The reliability models can be used to assess life expectancy of wind turbine components under anticipated life cycle loading conditions, as well as under accelerated stress test conditions.

The methodology for analysing OWT in the early design phase, using surrogate data, has applied, and in this first phase of research has produced comparative reliability results. The five generic drive train designs have been modeled, and reliability calculations have been completed on the basis of one year's operation as non-repairable systems, without maintenance.

The results of our comparative analysis of reliability characteristics for the 5 turbine drive- train sub-assemblies has concluded that the electronic-based hardware is the most vulnerable to failure within the one year period. The highest predicted failure intensity (failure rate) has been shown for the electronics of pitched rotor blades, converter AC/AC, generators and brakes. This future research of sub-systems reliability improvements is critical for OWT cost maintenance reduction. The failure mechanisms identified were interconnect galvanic corrosion as well as pitting corrosion present at any interface discontinuity in the electronic systems.

Approach: The basic approach taken is the probabilistic physics of failure approach inorder to model the effect of marine environments on the key failure mechanisms in power electronic systems for wind turbines and their interconnection to the grid. The second approach taken is to develop the UMD-OSW reliability analysis which is based on reliability prediction models in order to identify the criticality of OWT subassemblies. The results of the analysis will lead to an improvement of controllability and maintainability of off shore wind turbines. The developed reliability models will provide clear identification of required changes to any proposed WT system design, will assist the state in assessing proposed designs and will optimize maintainability approaches.

Outcomes:

The developed models include the important failure mechanisms and are also tied to the degree of complexity of OWT systems. The multiple designs offered by manufacturers are simplified to five generic drive trains. The initial failure distributions of critical sub-assemblies can be applied in reliability assessment and maintenance scheduling. Research studies show that failure rates are expected to increase with complexity. Our results identified that the control and drive train sub-assemblies such as the gearbox, generator and converter are the critical components. Research predicts that OWT sub-assemblies failure rates are relatively high and survivor functions are low: 5% to 10% after one year; calculations have been concluded on the basis of one year's operation as a non-repairable system, with no maintenance. The following three items summarizes the key outcomes:

- Developed robust reliability models for analyzing turbines at the initial design stage as well as for the comparison of the criticality of failure mechanisms.
- Defined OWT reliability block diagram using available reliability data from relevant industries
- Predicted sub-assembly failure rates in the offshore environment based on surrogate failure rate data and environmental adjustment factors.

Data collected:

- Several different turbine manufactures have been studied; turbines with power production from 3.0-6MW were selected for reliability modeling and analyses. The data base of subassembly specifications has been established.
- Design information has been collected, including component geometry, material properties, and assembly technologies for power electronics used in offshore wind turbines.
- Developed the first UMD and State of Maryland data base of surrogate date from multiple sources and in addition the rage of environmental "pi" factors for data application in the off shore environment.

Professor Christou's technical contributions encompass the development of materials surface and interface science and methodologies for achieving reliable high frequency devices, optoelectronic devices and circuits. Professor Christou's contributions established the critical relationships which exist between materials, materials surfaces and interfaces, process science, and reliability.