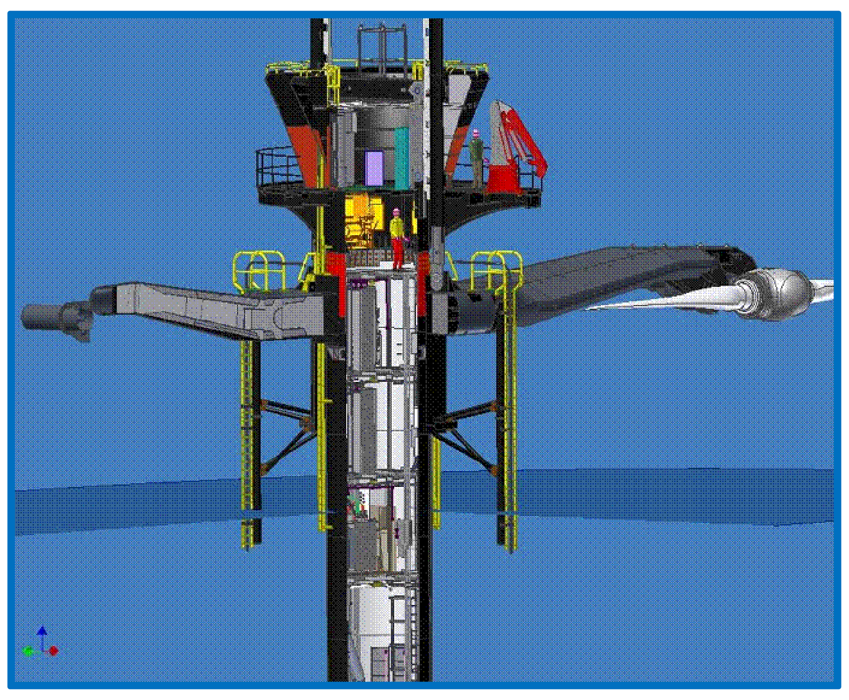
Reliability of Tidal Stream and Ocean Current Energy Converters

T. Delorm, Professor P.J. Tavner
Work Stream 8: WS 8.1 Reliability

This research focuses on developing a methodology to assess the reliability of tidal stream or ocean current energy generation converters in order to determine the most appropriate architecture

Introduction: Tidal energy converters have had a long history. In the Middle Ages, energy from tides was used in Britain and France for grinding corn. In the mid-20th century, tidal energy powered bulb turbines were installed in La Rance and the Bay of Kislaya and have been in operation for 30 years [1]. Today, new forms of tidal energy conversion in free-flowing tidal streams and ocean current are under study, but there is limited information on their reliability. The technological problems of extracting this energy source can "undoubtedly" be solved [2]. More than 50 tidal stream technologies have been identified around the world [3], however, only a few will be viable.

Case Studies: SeaGen (1.2MW) and Evopod, (1.2MW generic solution) with horizontal axis turbines have been chosen for reliability optimization, analysis and development of a generic reliability model. These choices are examined with the aim of finding the optimal generalized approach and solution to problems with this technology.



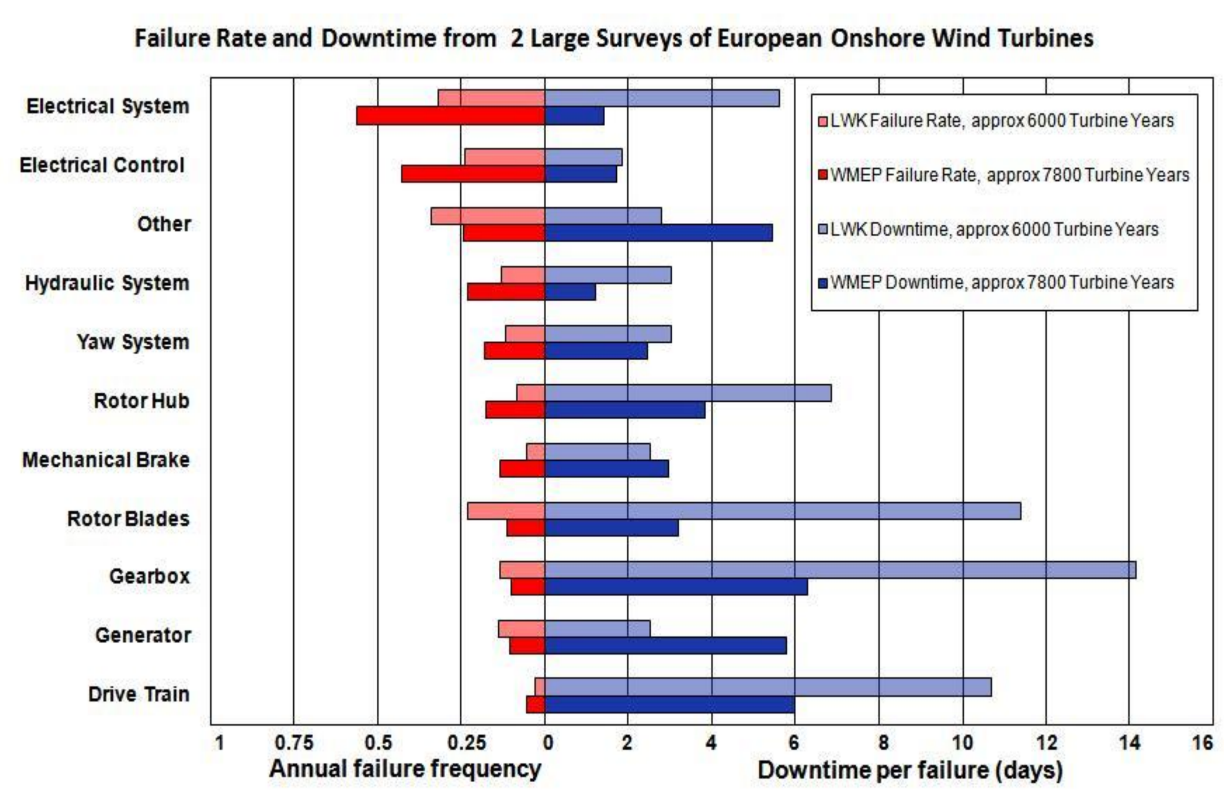
SeaGen , Marine Curent Turbines Ltd

1/10 scale Evopod , Ocean Flow Energy Ltd

Methods: Reliability modelling and predictions analysis are used to quantitatively evaluate the reliability of competing designs and direct design decisions.

Surrogate Data: Data are vital to developing reliability requirements for new technology. When no historical information is available, surrogate data are used. Wind turbines'(WT) data [3], [4] were used in this study for a number of reasons:

- The architectures of tidal turbines and WTs are similar;
- The core technologies of both turbine types are similar;
- The WMEP and LWK databases hold data on failure rates for 1500 WTs from industries in over 15 years of operation.



Steps Exercised in Developing Reliability Models:

- Selected Systems and Classified Subsystems
- Constructed Functional Block Diagram (FBD)
- Constructed Reliability Block Diagram (RBD) on Subsystem Level

Fig. 1: The SeaGen FBD

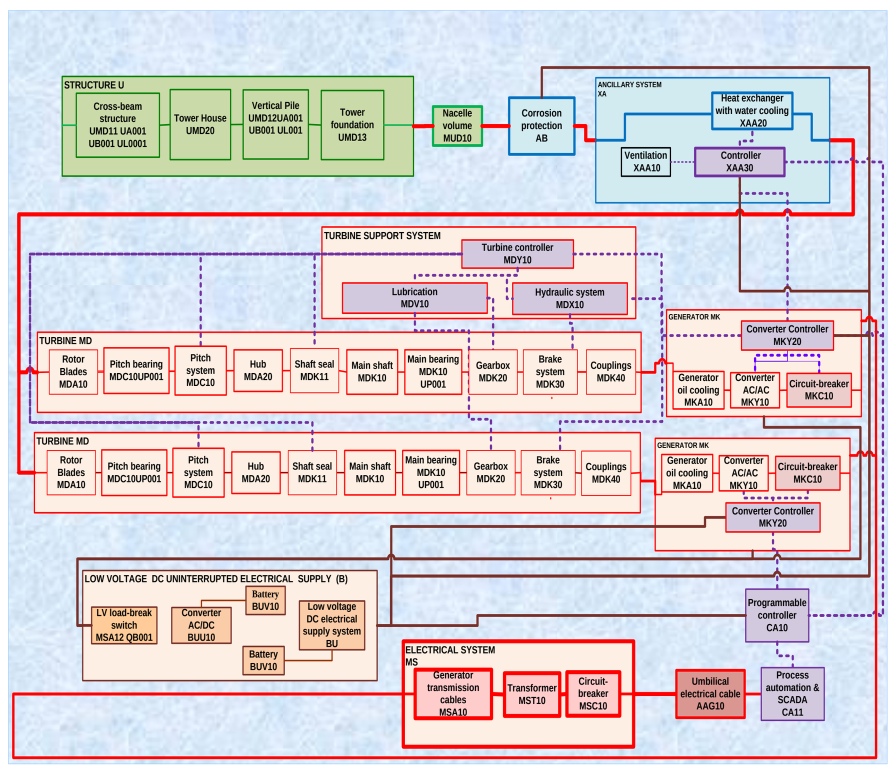
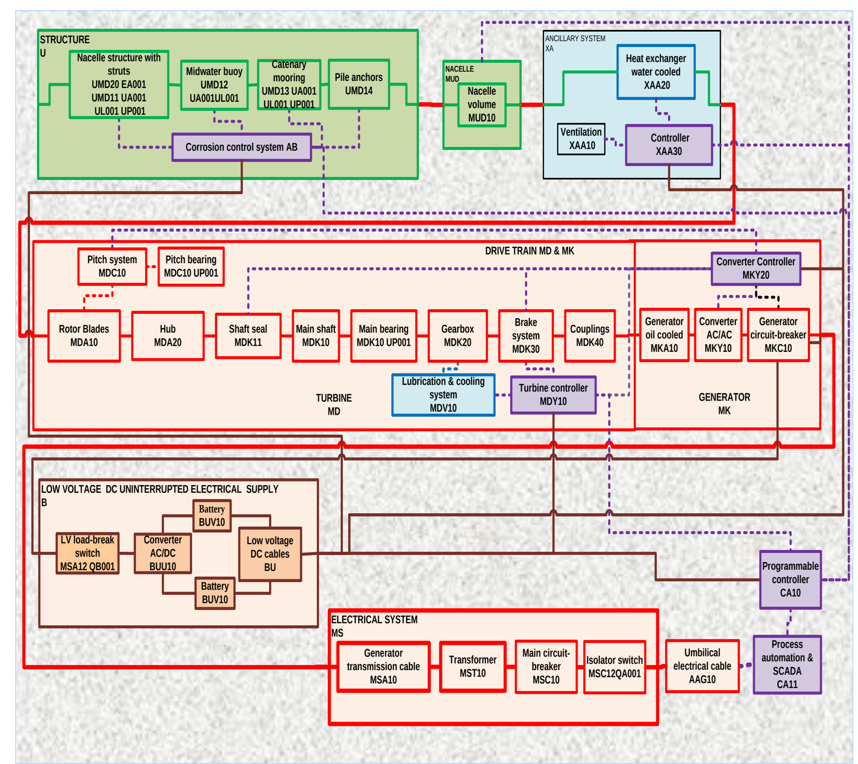


Fig. 2: The Evopod FBD



Parts Count Prediction: The method chosen for the system reliability prediction uses an average constant failure rate for each subsystem or component, assuming the time of failure of the subsystems is exponentially distributed, and the system is used in one environment.

Reliability Characteristics of the turbine drive trains of both devices, assuming that drive train RBD subsystems are independent of one another, have been analysed using the RBD and Parts Count Prediction Method. The Annual Failure Rates $\sum\lambda$ for total power production and Reliability Survivor Function *R(t)* have been calculated.

At this preliminary stage, failure rates are relatively high and survivor functions low compared to the availability of offshore wind turbines. These calculations have been done on the basis of one year's operation as a non-repairable system, with no maintenance.

An important result from this analysis is the influence that the parallel drive trains of the SeaGen have on the overall failure rate and survivability of the system, namely, that it is greatly in the interest of the designer to allow one or the other turbine to operate at one time as well as together, if reliability is to be improved.

Reliability Simulation: By analysing the FBD of the SeaGen and Evopod (Figs. 1-2), it was revealed that these tidal energy converters incorporate complex mechanical, electrical, control and structural systems with dependency status between them, which require advanced methods of reliability modelling for analysis. System simulations, such as the Monte Carlo and Markov Chain (MCMC), will be performed as methods for the evaluation of additional aspects of systems with complex topologies.

References

1. H. Stewart, G. L. Wick. Harvesting Ocean Energy. The Unesco Press, 1984. ISBN 92-3-101873-6
2. I. N. Usachev, T. A. Kadenkina and N. V. Rozanova. 'Utilization Plant for Power Generated at the Mezen' Tidal Electric Plant in the European Power System', Hydrotechnical Construction, 2000, Vol. 34, No. 12
3. The U.S. Department of Energy. Marine and Hydrokinetic Technology Database, 2009
4. B. Hahn, M. Durstewitz, K. Rohrig. 'Reliability of Wind Turbines' in Wind Energy- Proceedings of the Euromech Colloquium 464b 2005 Oldenburg, Springer Berlin Heidelberg New York, 2007, pp. 329-332
5. F. Spinato, P. J. Tavner, G. J. W. van Bussel, E. Koutoulakos. 'Reliability of wind turbine subassemblies', IET Renewable Power Generation, 2009, vol. 3, Iss. 4, pp.1-15

Durham University
School of Engineering and Computing Sciences

School of Engineering
and Computing Sciences
Durham University
South Road
Durham
DH1 3LE

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