RELIABILITY ASSESSMENT OF TIDAL STREAM TURBINES

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RELIABILITY IS ESSENTIAL FOR:

- Ensuring economic feasibility
- Protecting environment

AIM OF RESEARCH

To develop methodology for reliability and availability assessment of tidal stream turbines

OBJECTIVES

- Collect/derive data on failure rates/reliability of tidal turbine subsystems/components
- Develop a comprehensive model for turbine reliability analysis
- Develop a rigorous reliability approach for assessing different turbine configurations, including taxonomy and standardised naming of subassemblies
- Evaluate maintenance strategies for arrays of tidal devices

EVALUATION OF FAILURE RATES OF TURBINE SUBSYSTEMS/COMPONENTS

Approaches

1) Direct use of data on failure rates from similar subassemblies from other industries (e.g., NPRD-95, OREDA, Windstats and other wind turbine data)

2) Modification of the base failure rate to conditions of the tidal stream turbine by using “influence” multiplying factors

3) Direct probabilistic analysis of turbine subsystems/components

Data on failure rates from other industries

Annual failure rates for wind turbine subsystems

Subsystem	Tavner et al. (2007)		Ribrant (2006)		
	Germany	Denmark	Sweden	Finland	Germany
Rotor	0.223	0.035	0.052	0.210	0.230
Pitch control	0.097	0.007	-	-	-
Main shaft & bearings	0.024	0.011	0.004	0.000	0.050
Gearbox	0.101	0.040	0.045	0.150	0.120
Generator	0.120	0.002	0.021	0.080	0.050
Mechanical brake	0.039	0.014	0.005	0.040	0.100
Electrical controls	0.224	0.050	0.050	0.100	0.260
Hydraulics	0.110	0.031	0.061	0.360	0.210
Electrical system	0.341	0.019	0.067	0.110	0.490

Limitations of the approach

- Operational conditions of subsystems/components in tidal stream turbines are different from those in other industries
- Wide dispersion of available data, which mostly originates from repairable subassemblies
- Insufficient amount of data for a number of subsystems/components for statistically meaningful analysis
- Assumption about the constant failure rate may not be suitable for a number of subsystems/components

Modification of the base failure rate

$$\lambda_i = \lambda_{i,B} \prod_j C_j$$

$\lambda_{i,B}$ – base failure rate for *i*-th subsystem/component

C_j – influence factors representing the effect of various operational parameters on the subsystem/component reliability

Estimated annual failure rates

Component	Base failure rate	Adjusted failure rate
Bearing	0.105	0.013
Shaft	0.061	0.012
Seal	0.018	0.235

Limitations of the approach

- Possible synergistic effect of different operational parameters is ignored
- Failures of parts of subassemblies are treated as independent
- Assumption about the constant failure rate may not be suitable for a number of subassemblies
- Uncertainties associated with influence factors and models are not taken into account

Currently implemented extensions of the approach

- Uncertainties associated with influence factors are taken into account so that failure rates are treated as random variable
- Time-dependent reliability models are considered

Evaluation of the failure rate by probabilistic analysis

- An analytical/numerical model of the subsystem/component describing its performance under relevant operational conditions needs to be developed
- Uncertain parameters of the model are treated as random variables

If the failure rate is assumed to be constant

$$\lambda = -\frac{\ln(1-P_f)}{t_L} \approx \frac{P_f}{t_L}$$

Components being analysed:

- Blades
- Mooring system

MODELS FOR RELIABILITY ANALYSIS OF TIDAL TURBINE

Generic tidal stream turbine

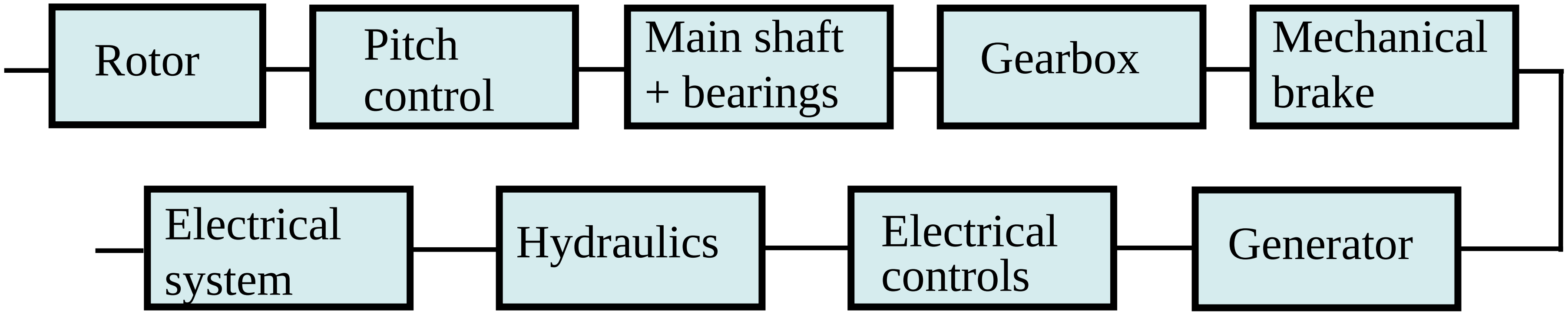
- Horizontal axis
- Free-stream (i.e., non-ducted)
- Fixed to seabed/floating
- Single indirect drive train with mechanical gearbox
- Pitch-controlled blades

The generic tidal stream turbine is very similar to commonly used wind turbines

Simple model - main assumptions

- Failure of any component of permanently working subsystems results in shut down of the turbine, i.e., failure
- Failure of any component of subsystems working on demand results in an increase of repair/maintenance time
- Failures of different components are independent
- Failure rates are constant

Reliability block diagram



Reliability of tidal turbine over time *t*

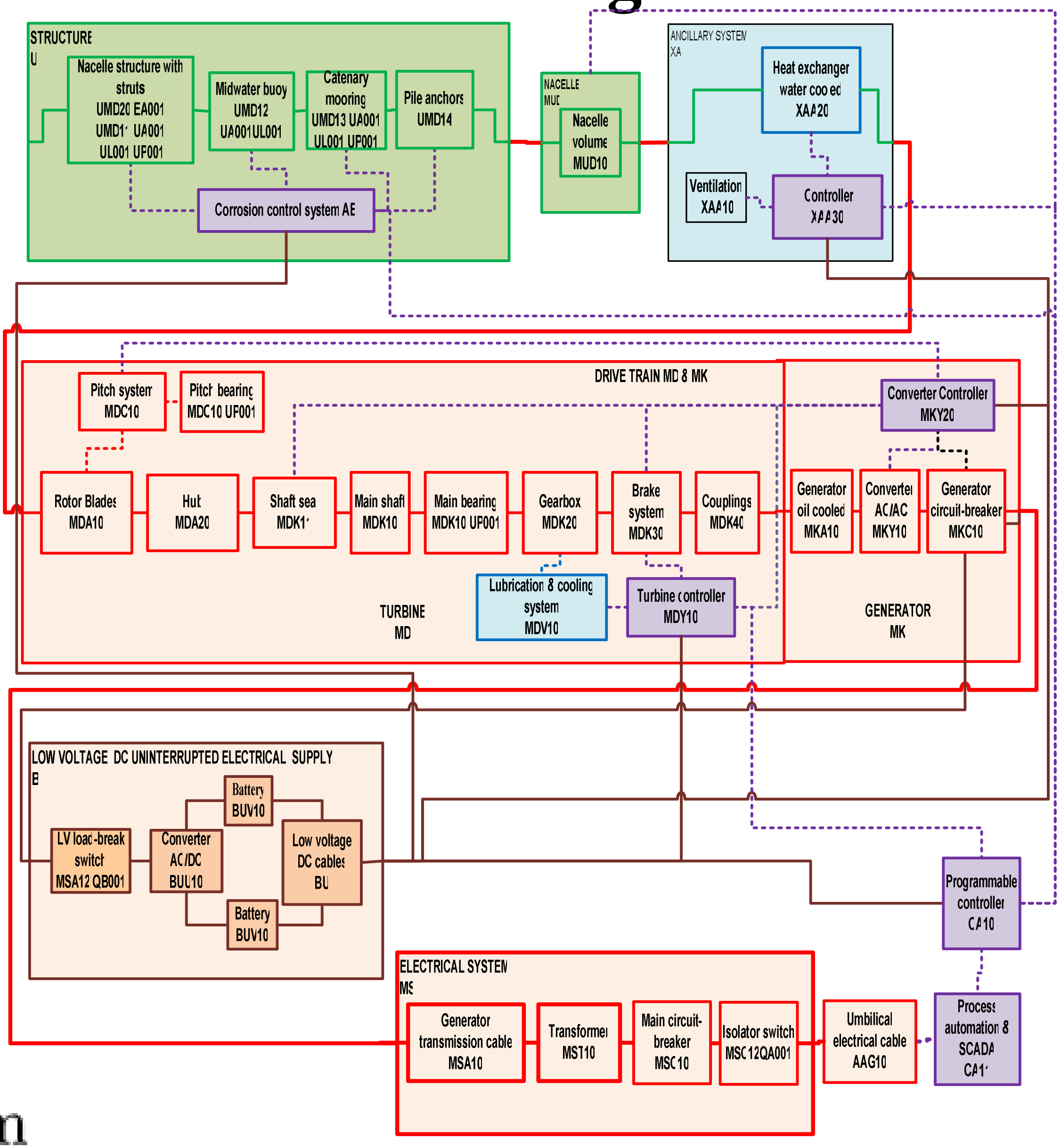
$$R_{sys}(t) = \prod_{i=1}^{n} R_i(t)$$

$R_i(t) = \exp[-(\lambda_i t)]$ – reliability of the *i*-th subsystem

n – the number of subsystems

Failure rate of generic tidal turbine based on the model and available data = 1.514 failures/year

Extended model – Functional Block Diagram



SUMMARY

- Methods for the evaluation of the failure rates/reliabilities of subassemblies of tidal stream turbines have been formulated and implemented

- Simple model for reliability analysis of a generic tidal stream turbine has been developed

- An enhanced model for reliability analysis of tidal stream turbines is at advanced stages of development

THANK YOU!