Reliability of marine energy converters

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Work stream 8: Reliability

Reliability assessment and failure rate uncertainty

The reliability of marine energy converters is pivotal to ensure viable projects with an acceptable level of availability. Based on [1] a reliability assessment was conducted using an analytical Reliability Block Diagrams approach [2]. The impact of failure rate uncertainties on the system failure rate was estimated, using a 2-parameter Weibull distribution with different shape parameters $\alpha$ and mean failure rates $\lambda$ [3].

$$R_S(t) = \prod_{i=1}^{n} R_i(t) \quad R(t) = e^{-(\lambda t)^\alpha}$$

Fig. 1: Generic Reliability Block Diagram for in-series sub-systems of a floating wave energy converter

Fig. 2: Estimated system reliability for 1 operational year without maintenance

Fig. 3: System reliability; optimistic, constant failure rate and pessimistic case

Specific reliability information

The large uncertainties necessitate specific reliability information. Two areas of particular interest were investigated [4, 5, 6]:

i) Expected fatigue loads for mooring lines, Fig. 4. ii) Mechanical loading and fatigue of dynamic marine power cables, Fig. 5/6.

Bayesian statistical approach

The Bayesian approach allows a failure rate estimate when reliability data is scarce. Available generic information is updated as specific information becomes available.

$$g(\lambda | x) = \frac{f(x | \lambda) g(\lambda)}{\int_0^\infty f(x | \lambda) g(\lambda) d\lambda}$$

Fig. 7: Prior, likelihood, and posterior distribution for umbilical failure rate update. Prior information derived from OREDA handbook data.

Fig. 4: Estimated annual load spectrum for leading mooring line

Fig. 5: Orcaflex model of armoured umbilical in lazy wave configuration

Fig. 6: Strain - cycle ($\varepsilon$-N) copper fatigue curve and expected number of conductor load cycles >1% strain range for typical one year of operation

Further Work

• Physical component testing of crucial components
• Improving reliability information through knowledge gained from field failures and dedicated testing

References


Fig. 2: Estimated system reliability for 1 operational year without maintenance

Total strain, Best fit NIST 177
Total strain, Best fit-2SD NIST 177
Plastic strain
Elastic strain

10.2% annual occurrence of sea state $H_s=2-4\text{m}, T=7-9\text{s}$ (data after HSE, 2001)
21.3% annual occurrence of sea state $H_s=2-4\text{m}, T=7-9\text{s}$ (data after Pitt, 2006)

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