ENERGY

5th International Conference on Ocean Energy, 4th-6th November 2014, Halifax

The acceptance of tests for approval in marine renewables

Claudio Bittencourt

Nov 2014

Contents

The Role of Testing

Design objectives

- To sustain loads liable to occur during all temporary, operating and damaged conditions if required;
- To ensure acceptable safety of structure during the design life of the structure;
- To maintain acceptable safety for personnel and environment;
- To have adequate durability against deterioration during the design life of the structure.
- DNV GL standards refers to different ways of carry out design:
  - design by partial safety factor method with linear combination of loads or load effects;
  - design by partial safety factor method with direct simulation of combined load effect of simultaneous load processes;
  - design assisted by testing; and
  - probability-based design.

The Role of Testing

- Testing can be of different types:
  - Destructive (ultimate capacity)
  - Life cycle (degradation)
  - Functional or performance related
  - Proof (confirms capacity before use)

  Destructive / Life cycle → Investigation / Research

  Functional / Proof → Confirmation / Compliance

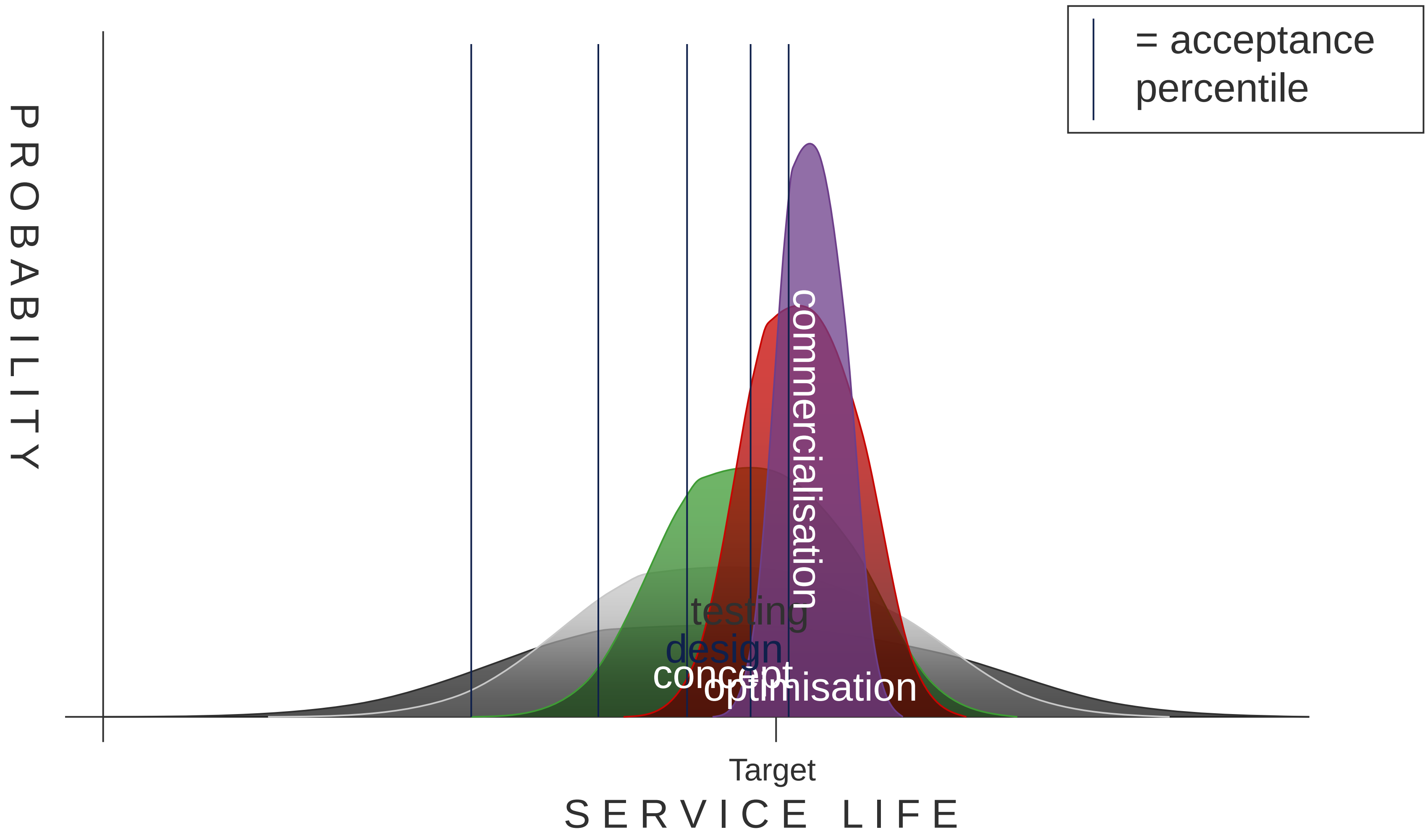
- Testing is normally carried out (together with extensive design assessment, simulations and small scale tests), as part of confirmation of design and fabrication suitability (component, sub-system, system or full product) at different stages of manufacturing, assembly, commissioning and sea-trial due to:
  - Scale and complexity of tests required,
  - Financial consequences of failure during the late stage
  - Large residual uncertainty following the testing (degradation aspects and non-symmetrical nature of results: a failure is a clear result, while a non-failure may not be sufficient to define the limits of survivability, for example)

Technology development phases and associated risks

	Phase 1 *Validation model (lab.)*			Phase 2 *Design model (lab.)*	Phase 3 *Process model*	Phase 4 *Prototype*	Phase 5 *Demonstration*
	Concept	*Performance*	*Optimization*		*Sea trials*		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5\text{–}10$)			$\lambda = 1:10\text{–}25$	$\lambda = 1:3\text{–}10$	$\lambda = 1:1\text{–}2$	λ = Full size
Tank	2D flume and 3D basin			3D basin	Benign site	Exposed site	Open location
Duration (inc. analysis)	1–3 weeks	1–3 months	1–3 months	6–12 months	6–18 months	12–36 months	1–5 years
Typical no. tests	50–500	250–500	100–250	100–250	50–250	Continuous	Statistical sample
Budget (€,000)	1–5	25–75	25–50	50–250	1,000–2,500	5,000–10,000	2,500–7,500
Excitation/Waves	Monochromatic linear waves (10–25 Δf) Panchromatic 5 reference	Panchromatic waves (20 min full scale) +15 classical spectra long crested head seas		Deployment: pilot site sea spectra Long & short crested classical seas Select mean wave approach angle	Extended test period to ensure all seaways included	Full scatter diagram for initial evaluation, continuous thereafter	

Thus, The normal risk management strategy is to gradually progress from low cost investigation at early stage, moving into simulations and finally, following positive outcome from previous steps, to commit to the large investment for construction of the device.

Risk Management - Handling Novelty and Uncertainty



Risk - Probability of Failure Classes

No.	Name	Description	Indicative Annual Failure Rate	Reference
1	Very Low	Negligible event frequency	10^{-4}	Accidental event
2	Low	Event unlikely to occur	10^{-3}	Strength / ULS
3	Medium	Event rarely expected to occur	10^{-2}	Fatigue / FLS
4	High	Event expected to occur once or several times during a lifetime	10^{-1}	Operation low frequency
5	Very High	Event expected to occur once or several times each year	1	Operation high frequency

Risk Consequences Classes

Class	Safety	Environment	Operation	Assets	Cost
1	Negligible injury, effect on health	Negligible pollution or no effect on environment	Negligible effect on production	Negligible	1K
2	Minor injuries, health effects	Minor pollution, slight effect on environment	Some small loss of production, less than a month	Significant but repairable	10K
3	Significant injuries and/or health effects	Limited levels of pollution, moderate effect on environment	Loss of production up to 100k	Localised damage, repairable in-situ	100K
4	Serious injuries	Moderate pollution with clean-up costs, serious effect on environment	Loss of production up to 1million	Loss of main function, significant repair needed by removal of part of device	1million
5	A fatality	Major pollution, disastrous effect on environment	Total loss of production around 10million	Loss of device, major repair needed by removal of device	10 million

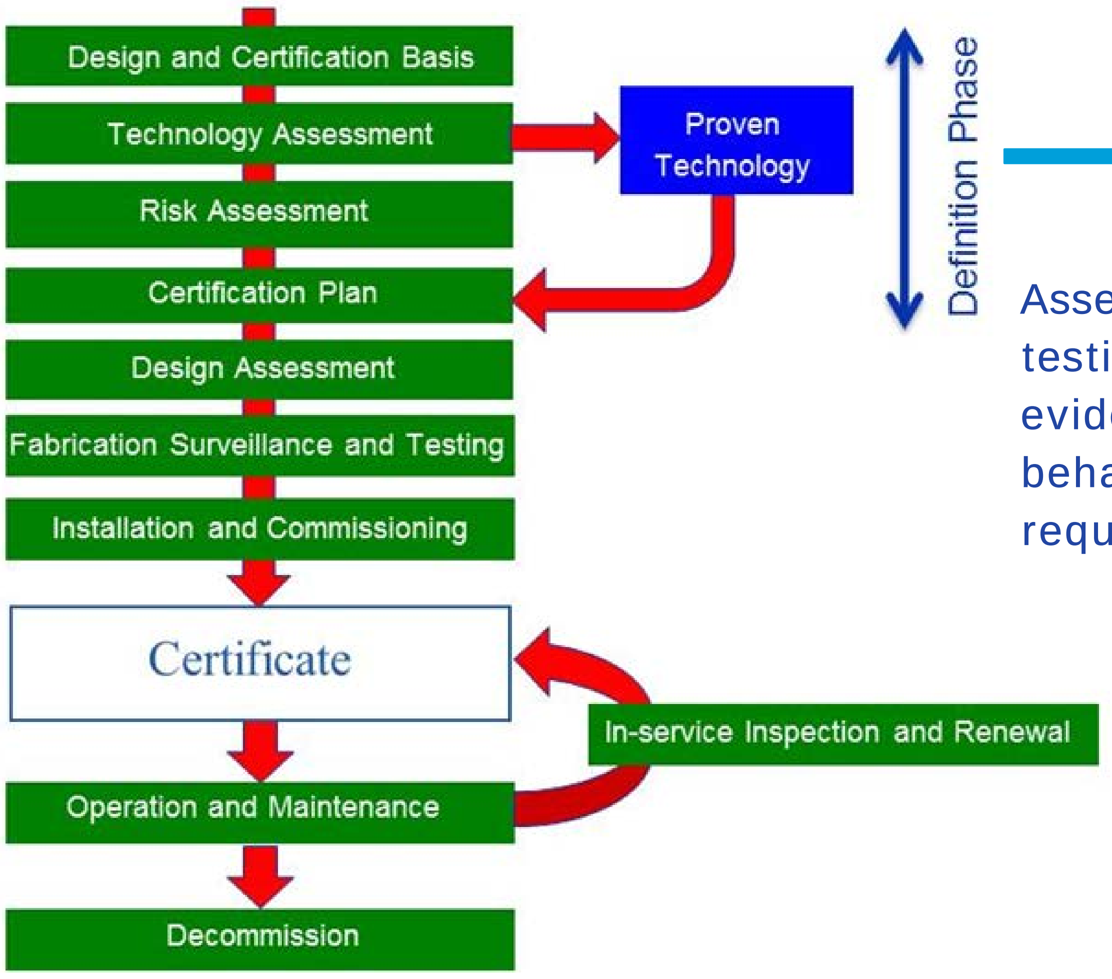
Risk Matrix

	Consequence				
Probability	**1**	**2**	**3**	**4**	**5**
5	Low	Med	High	High	High
4	Low	Med	Med	High	High
3	Low	Low	Med	Med	High
2	Low	Low	Low	Med	Med
1	Low	Low	Low	Low	Med

Where:

Low	tolerable, no action required
Medium	mitigation and improvement required to reduce risk to Low
High	not acceptable: mitigation and improvement required to reduce risk to Low (ALARP)

Risk based certification process



Assessment of the extent of testing necessary to establish evidence of satisfactory behaviour in line with the required targets.

Testing requirements

- Demonstration of acceptable margins for all conditions, i.e. all applicable combinations of critical parameters with due consideration of novelties and uncertainties.
- Statistically relevant.
- In cases where the complexity of the test and the clearly demonstration of satisfactory results is difficult, normally related to long term degradation (such as fatigue) or fault conditions, initial simulations and examination / monitoring during prototype deployment can be applied provided that the risks are acceptable and monitoring / control is effective.
- With the availability of test rigs, such as the 3MW Turbine Drive Train Facility at NAREC, the scope for testing whole complex systems and wider use the testing as part of the certification acceptance is possible. Normally with the objective to show conformity and solve “teething problems” in a controlled environment.
- The testing scope and the balance between uncertainties to be covered and the likelihood of conclusive results will make the decision on strategy for using testing for acceptance of testing as the main mean for certification approval of marine renewables.

Example of full extent of testing for approval

- A typical application for the proposed approach is a small tidal turbine. Considering the overall cost of the small turbine and the associated risk of failure after construction, a series of well-defined cost effective non-destructive tests with few turbines should be sufficient to demonstrate that the technology can survive the extreme loading and that the performance is as predicted.
- It is also possible, depending on the design life, simplified simulations and maintenance regime, that degradation mechanisms are also demonstrated to be in line with the required targets. The set of parameters to be monitored, the type and duration of tests and how much is performed before prototype deployment is to be defined based on the certification basis, technology assessment, failure mode identification and risk ranking.
- The certification plan resulting from these steps defines the analytical methods and the level of certification requirements at the design and fabrication stages and how they can be satisfied mainly by testing.

Typical risk for small tidal turbine

		CONSEQUENCES				
		1 1k	2 10k	3 100k	4 1m	5 10m
PROBABILITY	5 10^{0} /year	Low	Medium	High	High	High
	4 10^{-1} /year	Low	Medium	Medium	High	High
	3 10^{-2} /year	Low	Low	Medium	Medium	High
	2 10^{-3} /year	Low	Low	Low	Medium	Medium
	1 10^{-4} /year	Low	Low	Low	Low	Medium

Low and medium risks for strength and degradation

Small tidal turbine and testing

- In this case, the high risk is associated to very frequent events (operation level). Thus, it is well within the possibilities to be covered under tests for the whole turbine. Also, it is expected that the small tidal turbine is probably designed with dimensioning governed by fabrication restrictions and minimum dimensions, thus not designed at the limit of the safety factors. Therefore, risks are likely to be even lower with degradation mechanisms likely to be well under control.
- With analyses of low level of complexity for indication of the magnitude of stresses and fatigue damage, testing will be able to complete the final evaluation of turbine.
- Performing testing under actual (design) conditions with all details of the technology in full scale is cost effective and efficient as well as compatible with the economics for a small tidal turbine.

Conclusions

- The certification process follows an incremental, risk-based approach.
- Certification provides traceability and demonstrability of the targets achieved, how they have been met, and evidence that the device can be expected to operate reliably within the limits specified in the Certification Basis.
- This is normally achieved by review of simulations and detailed design, fabrication and commissioning surveillance as well as follows up during the prototype deployment. This process is compatible with the control of risks and uncertainties compatible with gradual investment.
- However, it is possible that within certain range of risks, testing can be the main venue for approval during the certification. This is to be evaluated considering the outcome of the definition phase of the certification process.
- The testing needs to consider all relevant parameters and conditions in order to provide demonstrability of achieving the certification basis with adequate safety margins and compatible with the risk of the technology to achieve success.
- The risk based requirements in the new DNV GL standards for certification of marine renewables provides the suitable approach to deal with the diversity of the technologies and range of risks with one methodology. The use of extended tests for approval is one example of this robust approach.

The acceptance of tests for approval in marine renewables

Claudio Bittencourt
cbf@dnvgl.com

www.dnvgl.com

SAFER, SMARTER, GREENER