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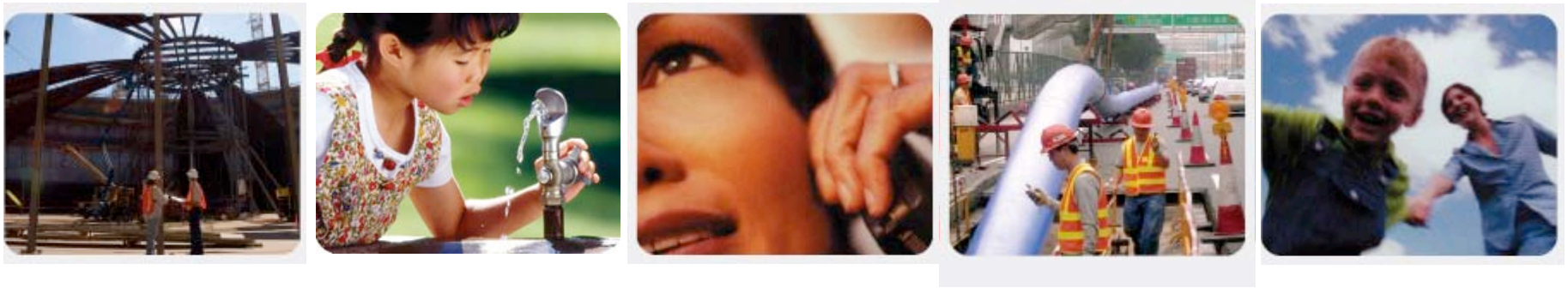

Approaching & Demonstrating Survivability

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B&V - Renewable Energy Team

- B&V – Global Engineering Consultant-Contractor – 9,000 staff
- B&V has over 80 years experience in renewable energy
- Global team with over 100 full time staff, 20 in UK, 70 in USA

UK Expertise in:

- Tidal Energy
- Wave Energy
- Biomass
- Hydro

USA Expertise in:

- Biomass
- Hydro
- Wind
- Solar, Geothermal

Global marine expertise resides mainly in UK. UK leads global projects with local support from global offices

B&V – Marine Energy

We provide:

- Strategic Planning
- Resource Analysis
- Feasibility Studies
- Project Design
- Project Development
- Technology Design
- Environmental Permitting
- Due Diligence

We are working on Marine Energy projects in:

- UK
- USA
- Australia & New Zealand

<u>Covering:</u>

- Tidal Stream, since 1986
- Wave, since 1991
- Tidal Barrage, since 1975

Survivability: What does this mean?

The ability of a device/system to survive:

- Adverse (discrete) conditions, e.g. extreme events
- Long-term conditions, e.g. fatigue / corrosion

Need to consider:

- The device structure itself
- The supporting structure or mooring system
- On board equipment
- Systems & sub-systems

Why Consider Survivability?

The survivability of a device can impact:

- The long term success of a device (GWh of generation)
- Availability and reliability of a device (MWh, price)
- Project costs (IRR, O&M, insurance, third party)
- Investor & stakeholder relationships
- Public relations & public opinion
- Value of company
- Value of your stake

Approaches to Considering Survivability (1/2)

- Consider it appropriately at all development stages
- Consider it in conjunction with RAM (Reliability, Availability, Maintainability) studies, i.e. as part of the 'Reliability Case' that should be developed
- Consider RAM studies as economic trade-off
- Capex & Opex costs of achieving reliability / availability vs. additional / lost revenue. Include statistical weather impacts on O&M costs (retrieval and re-deployment)
- Consider HAZID → HAZOP → FMECA assessment

Approaches to Considering Survivability (2/2)

- Design in accordance to Offshore Standards
- Estimate extreme and long-term loadings on device
- Specify suitable operating components / systems
- Record all work throughout all processes
- Log data and information from all tests, feedback to design

Failure Modes, Effects, and Criticality Analysis (FMECA)

A FMECA allows a developer to:

- Identify the important failure modes in the device or particular system under consideration, and their effects
- Build up the probability of failures from individual components to failures in sub-systems and systems
- Evaluate the criticality of failures and undertake mitigation
- Focus on high risk failures to ensure they are ‘As Low As Reasonably Practical (ALARP)’
- Identifies key failure modes to be assessed during design

Offshore Standards & Environmental Conditions

- There are currently no Offshore Standards specific to the design of marine energy converters
- EMEC suite of standards & guidelines are being developed
- DNV standards currently amongst most widely used by the industry due to their development in the MEC.
- Devices generally located in aggressive environments. Need to consider:
  - Currents (tidal stream / wind generated)
  - Waves
  - Water levels (tide levels & storm surge)
  - Wind (if device protrudes above sea surface)

Extreme Environmental Conditions

Published or recorded data

+

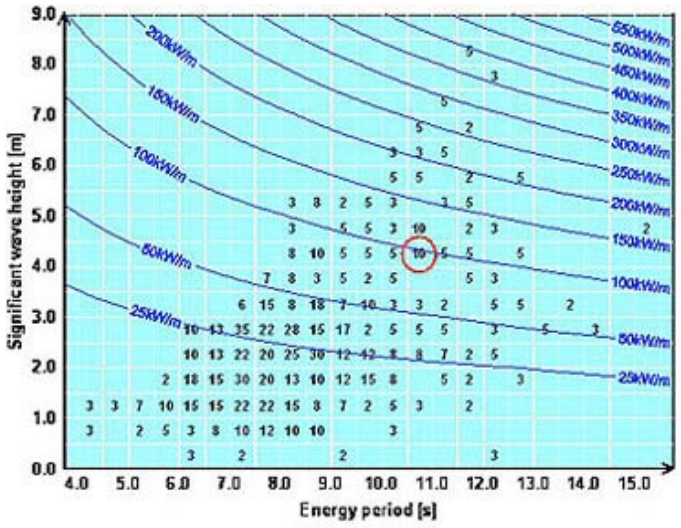
Pre-determined return period

+

Extrapolation techniques

=

Extreme conditions



Wave Scatter Diagram

Design Loads & Structural Survivability

- Permanent dead loads (self weight)
- Extreme environmental loads (drag, wave slam)
- Operational loads (e.g. reaction / turbine loads)
- Accidental loads (e.g. FMECA failure modes, debris etc.)
- Fatigue (cyclical) loads
- Data from numerical and/or physical models
- Type of material (steel, concrete)
- Limit state design in accordance with offshore standards (SLS, ULS, ALS & FLS)
- Harmonic assessments
- Durability (i.e. corrosion protection)

On-board Equipment & Systems

Survivability can be enhanced through:

- Adoption of greater factors of safety to account for unknowns
- Use of tried and tested ‘off the shelf” components
- Duplication of components & systems (redundancy)
- Use of ‘survival’ operation modes
- Adoption of ‘failsafe’ mechanisms
- Preventative & predictive maintenance

Workmanship

Ensure the quality of workmanship through:

- Preparation of ‘Specification’ documents
- Use of recognised QA and QC procedures
- Examinations (Non Destructive Testing)
- Testing of critical components or sub-systems
- Accelerated testing

Demonstrating Survivability

- Basis of Design Statement
- Overview summaries of key design activities
  - Offshore Standards applied
  - Derivation of environmental conditions
  - Derivation of extreme and cyclical loading
- Details of FMECA assessments (with backup information on data derivation, mitigating actions etc.)
- Details of survivability enhancements (e.g. redundancy)
- Control of design process & workmanship

Conclusions

- The appropriate consideration of the survivability of a device is essential to its success, i.e. at all stages of development
- Adopt a logical approach to avoid abortive work, especially the use of a Design Basis statement to drive all design
- Tools (e.g. FMECA) are in place to assist developers
- Record all work to demonstrate to potential investors

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MARINE ENERGY SERVICES

SAMPLE WAVE & TIDAL ENERGY PROJECTS

Renewable Energy

The B&V global renewable energy group has current experience in all major renewable energy technologies and is actively engaged in projects from early concept definition and research to turnkey project execution. This experience extends across all sources of sustainable energy including:

- Tidal
- Wave
- Biomass
- Hydro
- Wind
- Solar

Wave and Tidal Skills

- Resource Assessment.
- Concept development.
- Design and Technology development.
- Basic and detailed design of prototypes.
- Cost-of-energy optimisation.
- Due Diligence.
- Programme Management.

Using our innovation, value engineering, and bespoke key parameter optimisation programmes, we work with technology developers to prioritise areas for design development in order to increase performance and decrease costs.

B&V has been involved in wave and tidal technologies since 1975.

Marine Energy Accelerator (MEA)
The Carbon Trust, 2007 - Ongoing
Black and Veatch (B&V) is currently assisting the Carbon Trust in the MEA, with the aim to accelerate cost reductions in the marine renewable industry. Work to date has included an initial assessment of a novel wave energy device, and a tidal stream resource assessment.

Due Diligence on a Tidal Stream Device
Confidential Client, 2007 - Ongoing
B&V is carrying out a due diligence on a tidal stream device for an equity investor. The independent verification of the device incorporates the development of the testing methodology, witnessing of the sea trials, results analysis, and development of next steps.

Technical advice for Tidal Stream Developer
Confidential Client, 2007 - Ongoing
B&V is providing technical and economic services to assist a tidal stream technology developer to achieve a commercially viable device (inc. patents review, design scaling).

Verification of R&D for a Tidal Stream Device
Swanturbines, 2007 - Ongoing
B&V is carrying out the independent verification of Swanturbines R&D plan in order to satisfy the requirements of the UK's DBERR grant.

Resource & Techno-economic Assessment on Tidal Stream
Pacific Gas and Electric Company, 2006 - Ongoing
B&V is undertaking a detailed resource assessment of potential sites for development of tidal stream power in California. B&V is also advising PG&E on the techno-economic aspects of the potential projects.

Wave Device Optimisation
C-Wave, 2006 - 2007
B&V undertook an optimisation of the design of the walls and space frame of C-Wave.

Technical Advice on Wave and Tidal Stream
Project Developer, 2004 - Ongoing
B&V acts as the technical adviser to an energy project developer interested in exploring the potential for wave and tidal stream energy generation in Australia and New Zealand. This study includes resource assessments, technology review and cost estimation.

Vendor's Due Diligence
Marine Current Turbines, 2006
B&V undertook a Vendor's Due Diligence for MCT which included an overview of the current technology; a detailed assessment of the current engineering and predicted performance of Seagen, and a review of lessons learnt from Seaflow. B&V carried out independent economic modelling of the costs of Seagen to verify MCT's economic model, used the most up-to-date scaling and learning techniques to predict future costs, assessed optimal farms and commercial threats, and reviewed MCT's future designs.

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Thank you. Questions?

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