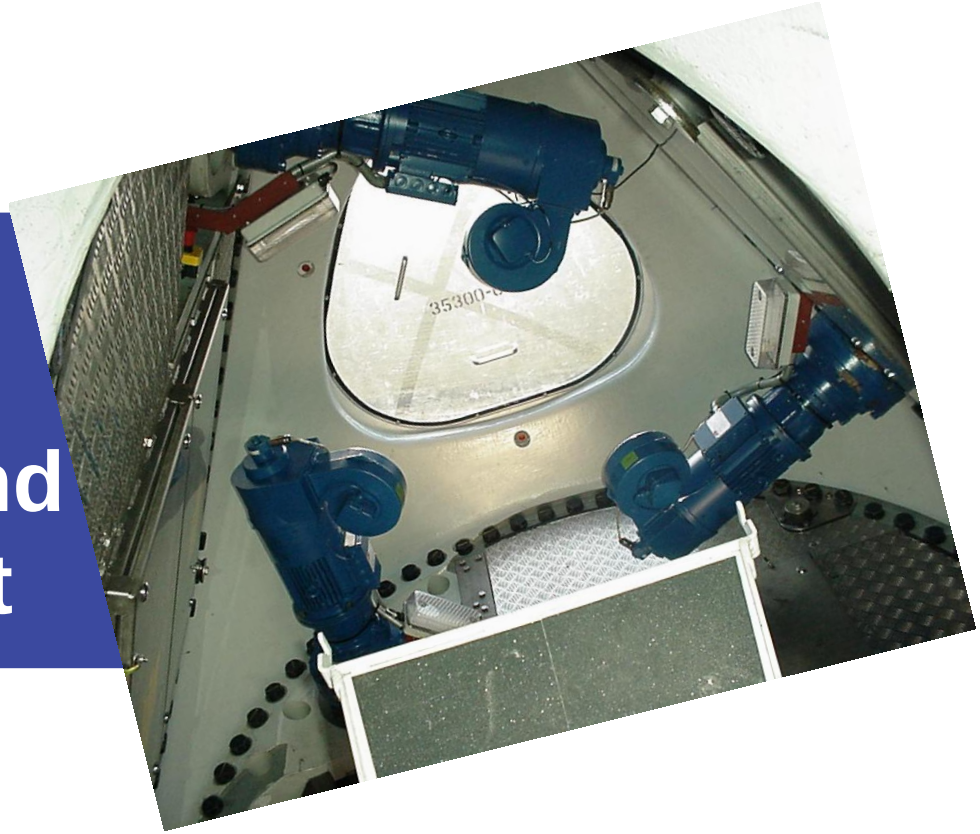
5th Annual
International Wind O&M Forum for Power Producers
19th - 20th February 2013 | RADISSON BLU HOTEL | Hamburg, Germany
Organized by WIND ENERGY update

Implementing a reliability centred approach during wind turbine development



Hamburg, 20 February 2013

Bruce Valpy

BVGassociates

Reliability centred approach during wind turbine development

Introduction

Contents

- Why focus on reliability
  - Cost of energy
  - Health and safety
- Reliability centred approach
  - 10 steps to success

Selected clients

BVG Associates

- Market analysis and business development
  - Supply chain development
  - Economic impact assessment
  - Support to industrialisation
- Technical innovation & engineering analysis
  - Support to investment in technology
  - R&D programme management
  - Design and engineering services
- Project implementation
  - FIT project development (UK only)
  - SCADA & condition monitoring
  - O&M technical support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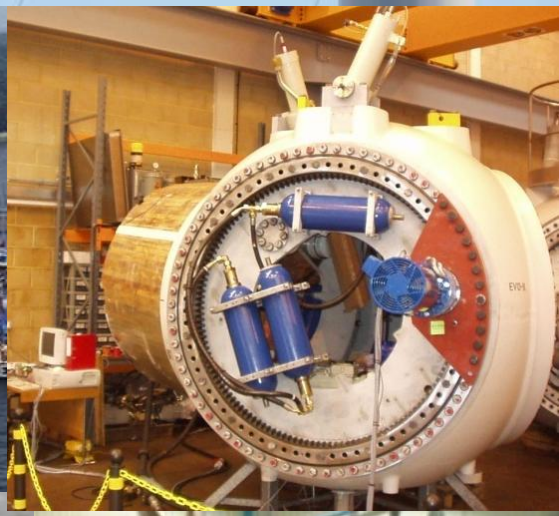


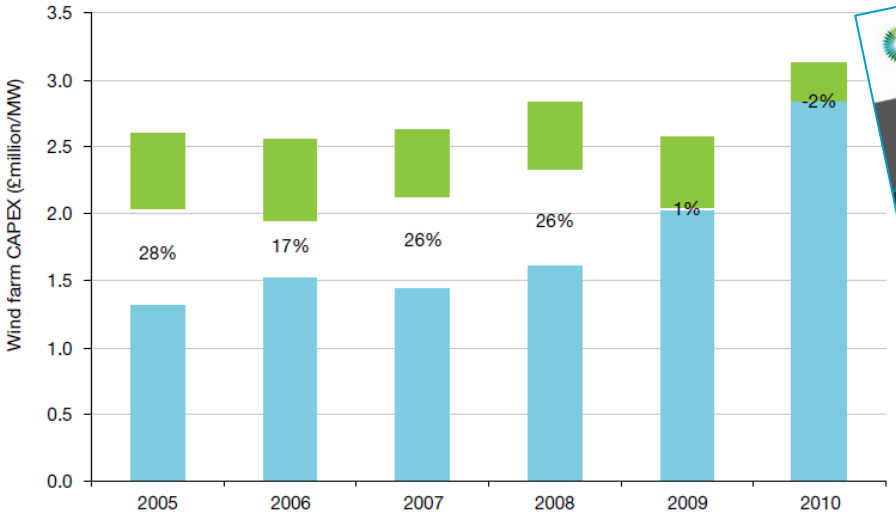
Cost of energy

Health warning

CAPEX has been going up, not down

- Need to understand the past before talking about cost reduction in the future
- Between 2003 and 2010, CAPEX increased (blue bars)
- Much can be explained by change of site conditions
- Much of the rest can be explained by market conditions
- Due to increases in site wind speeds and use of larger turbines, LCOE decreased during period despite CAPEX increase
- CAPEX stabilised 2010-12

Figure 8: Gap between quoted costs and estimated and compensated CAPEX based on 2010 costs



Cost reduction pathways study

Overview

Context

- 2011 UK Government Energy white paper:
  - Central scenario 13GW by 2020
  - Minded to support to 18GW if cost of energy reduced – target £100/MWh

- The Crown Estate cost reduction pathways study established to evidence what industry thinks could be done
  - Supply chain, finance and technology work streams

- Published summer 2012

Methodology in numbers: techn… …rk stream

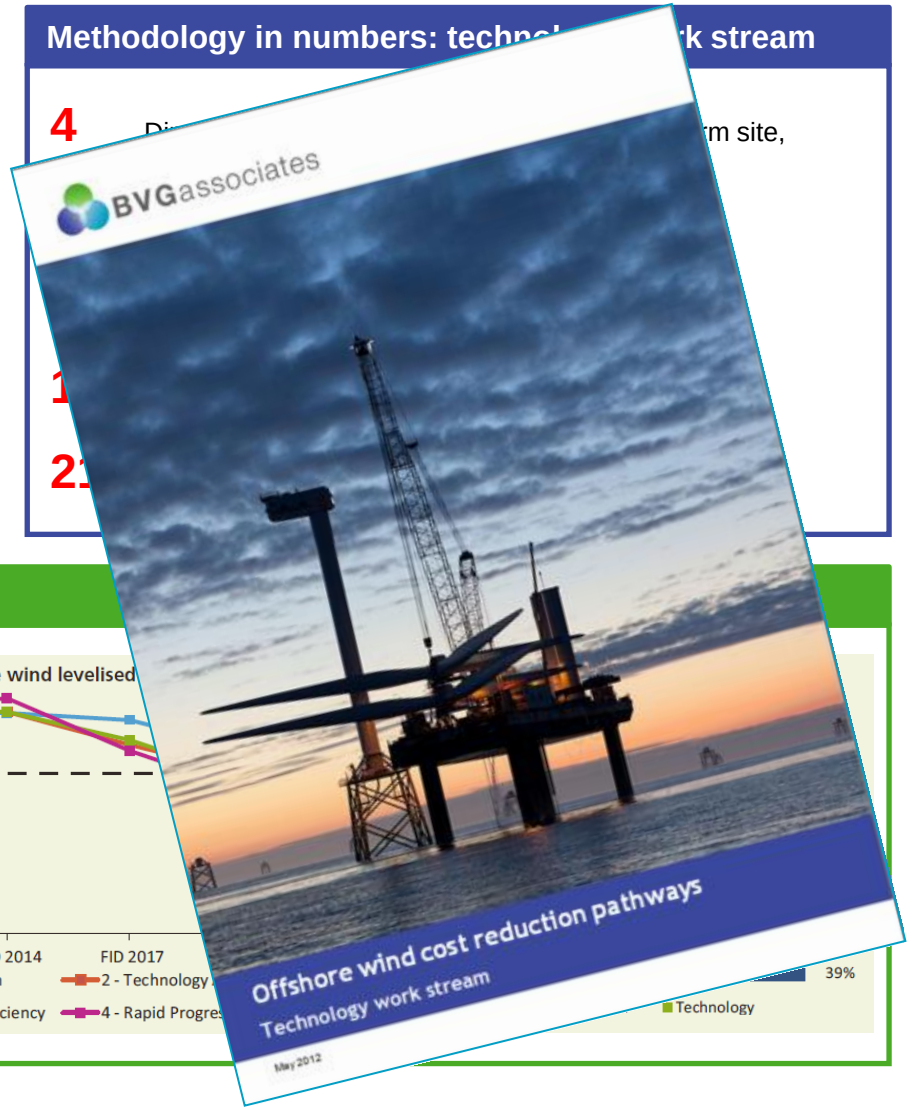
4 Di… …rm site,

1…

2…

Cost reduction pathways study: results

- Given right external conditions, industry can meet target:
  - Confidence in market size to beyond 2020
  - Smooth and timely transition under EMR
  - Planning consent timelines reliably met
  - Clear and predictable offshore grid regulatory framework
  - Facilitation of new technology introduction
- To deliver, industry also needs to work together:
  - Best practice, standardisation, risk management, accessing new finance

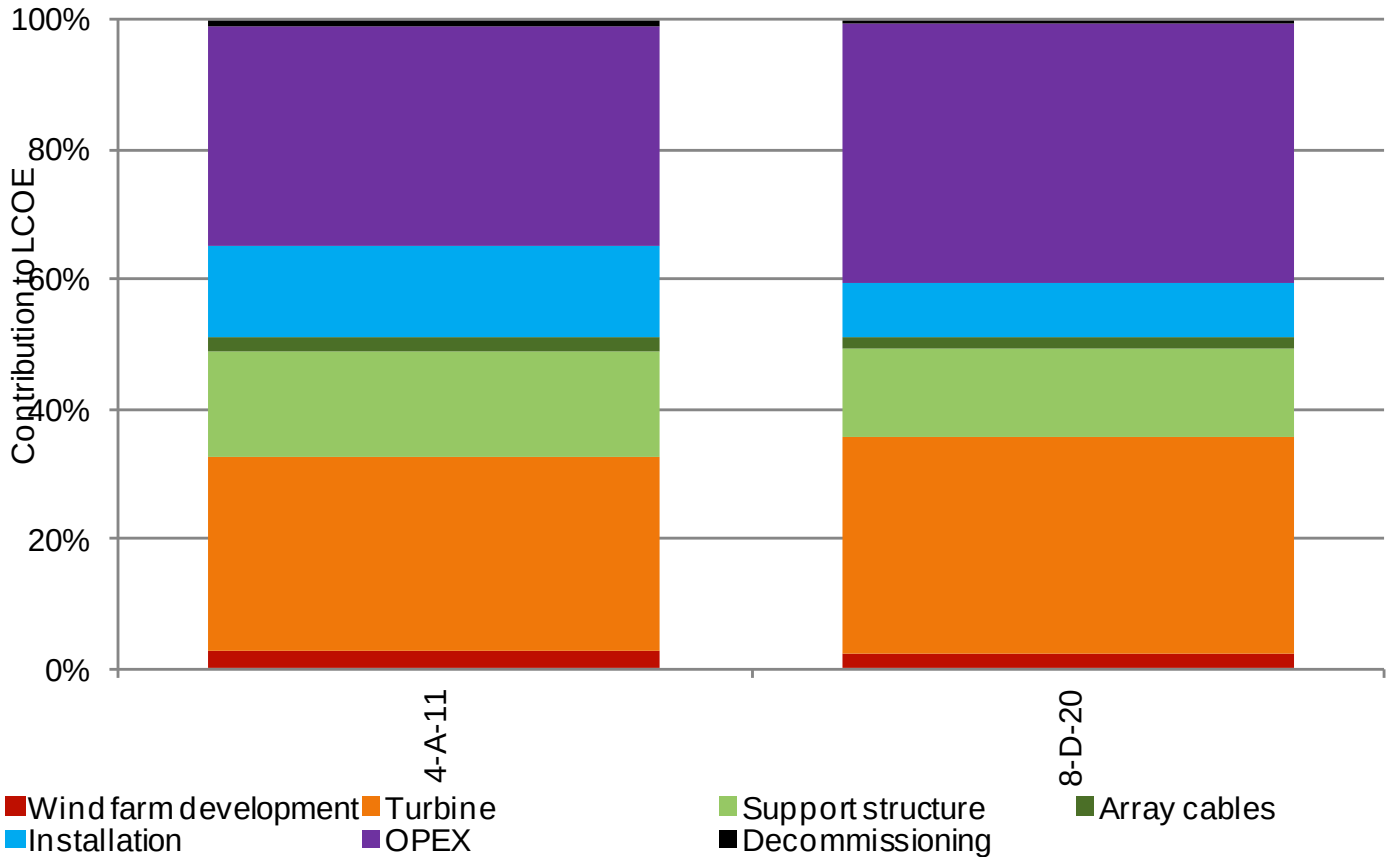


Why focus on reliability

The case for focus on wind turbine reliability

OPEX is already 1/3 of LCOE and growing

Source: BVG Associates

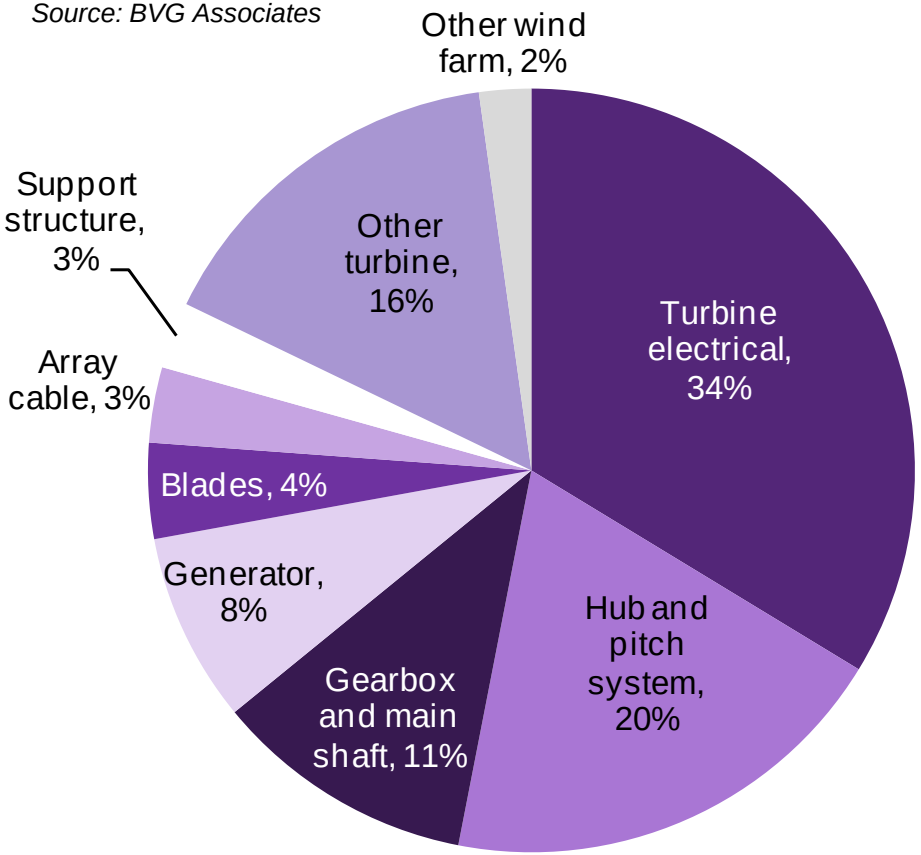


Why focus on reliability

The case for focus on wind turbine reliability

Most non-fixed OPEX is turbine-related

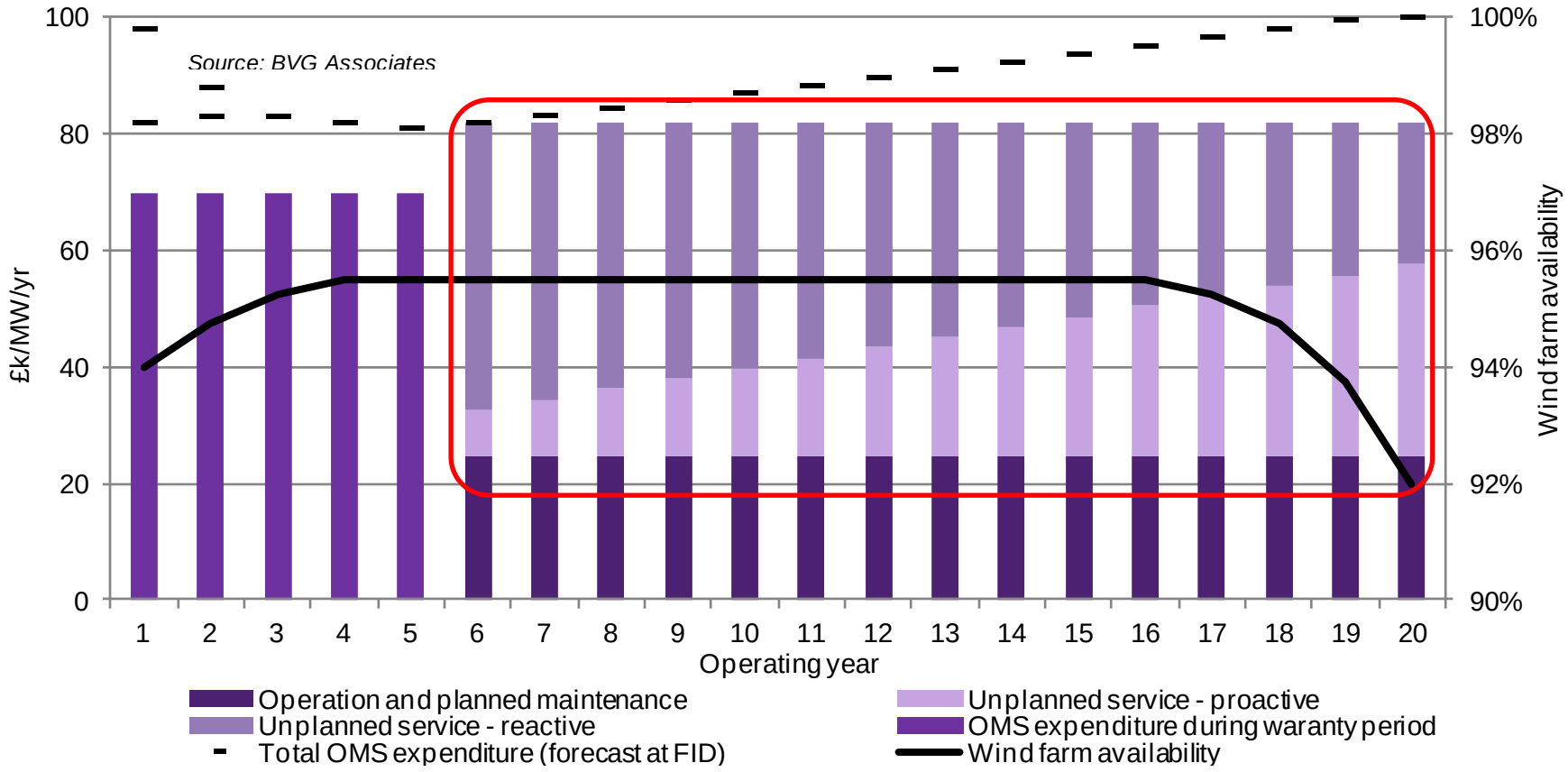
Source: BVG Associates



Why focus on reliability

The case for focus on wind turbine reliability

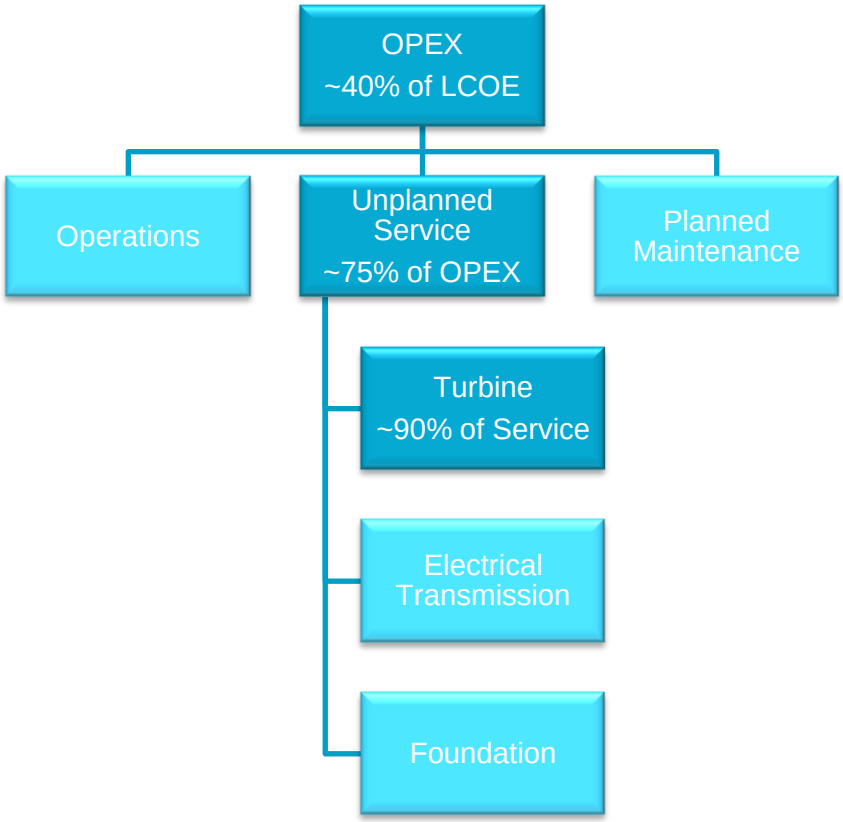
Most OPEX is unplanned service – reactive or proactive



Why focus on reliability

The case for focus on wind turbine reliability

Summary



If...

- If turbines were 100% reliable, so just needed visits for planned maintenance...
- OPEX down 68%
- Lifetime expenditure down 27%
- Lost energy down by 90%
- LCOE down by 30%

- Visits down 70%
- Accidents down by >80%
- Increased certainty would increase pool of investors and hence decrease cost of capital

Why focus on reliability

The case for focus on wind turbine reliability

Due diligence - experience

- ✓ Lots good
- × Few components / systems tested thoroughly
- × Poor justification for component survival (beyond calculations)
- × Main component exchange not designed in / tested
- × Not possible to easily replace wear parts
- × Poor / incomplete manuals and troubleshooting guides
- × Track record of unreliable systems / repeat faults
- × Training strategies not implemented
- × Site work records incomplete
- × SCADA report errors
- × Significant inefficiencies on site
- ✓ Type Certificate (does not consider the above)

Where our experience comes from

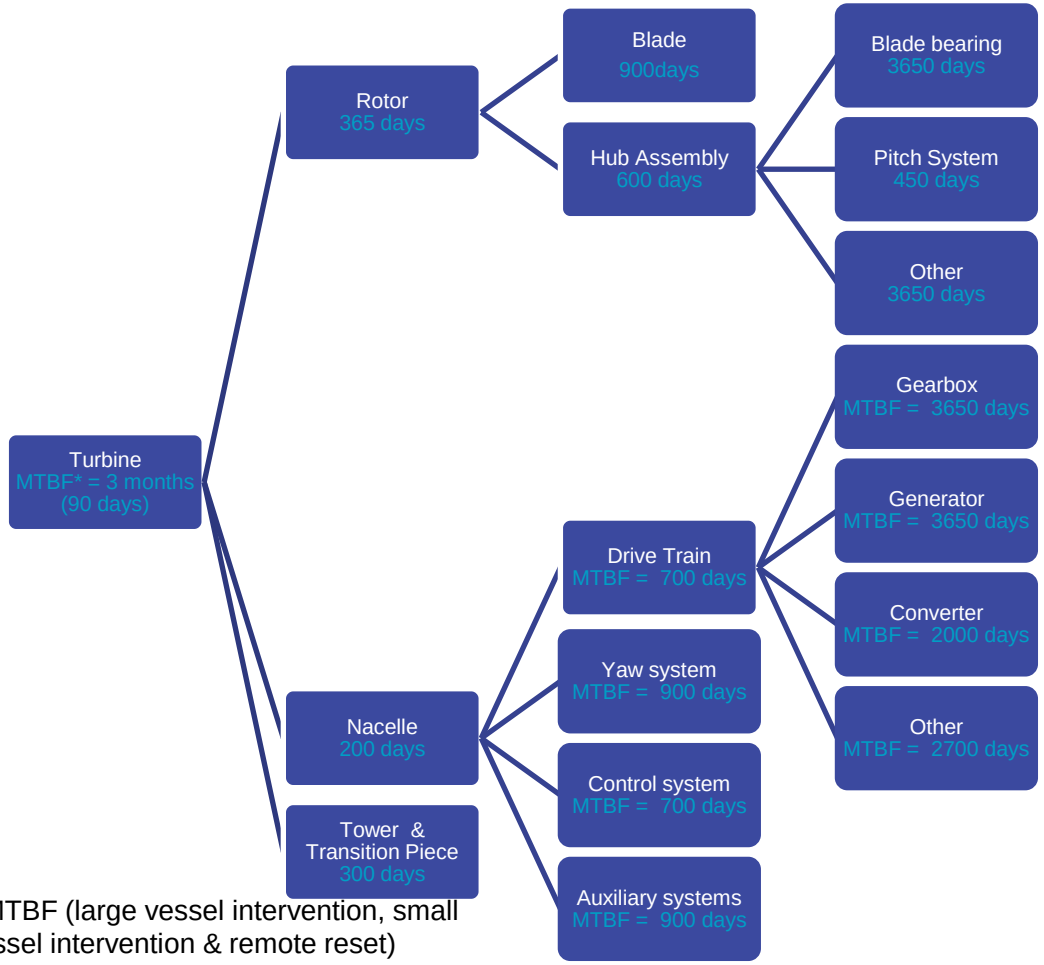
Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

1. Reliability and OPEX budgets (and model)

1a. Reliability budget



* MTBF (large vessel intervention, small vessel intervention & remote reset)

Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

1. Reliability and OPEX budgets (and model)

1b. Reliability and OPEX model

Product design and verification
Justification for MTBF data based on:
- Operational experience
- Reliability analyses
- Sub-system and component verification and testing

→

MTBF
Three sets of MTBF data, self-consistent down to sub-system/component level*:
- Simple resets
- Small vessel interventions
- Large vessel interventions

+

Generic design site conditions
- Distance to OMS port
- Range of other physical site parameters
- Wind and wave climate (inc. persistence data)

+

OMS strategy
- Failure response strategy (MTBR)
- Weather capability
- Vessel-related, labour and spares costs

←

OPEX
Taking into account lost revenue

Availability
Energy- or time-based

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Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

3. Component reliability reviews

2. ‘Rules of thumb’

1. Reliability and OPEX budgets (and model)

2. ‘Rules of thumb’

- A ‘small boat’ intervention costs average €15,000
- Worth spending €1k CAPEX if can save €X OPEX per year
- Downtime costs average €8k/day (€20k for windy day)

3. Component reliability reviews

- FMEA – hard to do well, balanced across range of components
- Logic and probalistic FTA
- Six sigma

Project ID	System				Facilitator			Participants	
XXX	PITCH CONTROL SYSTEM (INC. SLIP RINGS)				BAV			XX, BAV	
ROW	PART	PART FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS OF FAILURE (assuming failure detection OK)	FAILURE DETECTION ON TURBINE	SEV	POTENTIAL CAUSE(S) OF FAILURE	OCC	DESIG
A1	Blade Bearing	ROTATE EASILY	STOPS ROTATING instant - seize	PITCH FIXED on one blade Turbine shut down by control system using generator	Pitch control error and pitch asymetry errorwhen pitch movement demanded.Codes [5571-5674 and 5723-5724]	8	Extreme overload (large collision); fracture; undetected roller / raceway fatigue failure;	2	Turbine loa detailed sp calcs (ultir
A2			STOPS PITCHING gradual - notchy	DAMAGE to gear teeth, pitch gearbox & motor & TURBINE SHUTDOWN	Pitch position [L1] & regular movements [t1]; also motor current [L11]	6	Extreme or fatigue overload; poor lubrication	7	Little supp similar app
A3			STOPS PITCHING gradual - increased friction	DAMAGE to gear teeth, pitch gearbox & motor & TURBINE SHUTDOWN	Motor current checks during slack water [t2, T1]; also motor temperature [L2]	6	Extreme or fatigue overload; poor lubrication	7	Little supp similar app interpret fa
A4		TRANSFER predicted LOADS	TRANSFER TOO HIGH LOADS to bolts	Bolt FAILURE	Service inspection	5	Higher prying loads than predicted	7	Turbine loa calculation

Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

4. Test and verification

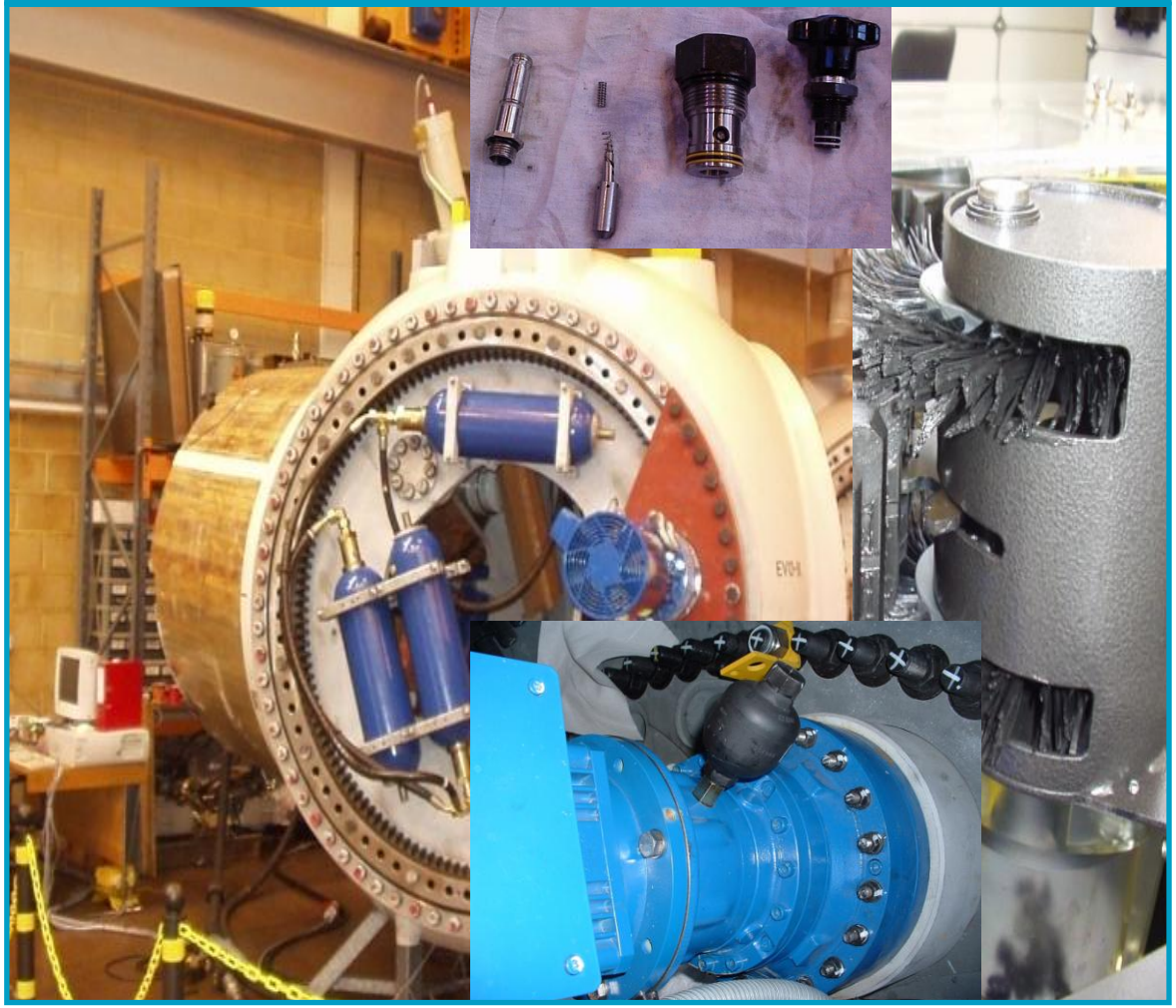
Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

4. Test and verification



Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

5. Demonstration of maintenance procedures
4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

5. Demonstration of maintenance procedures

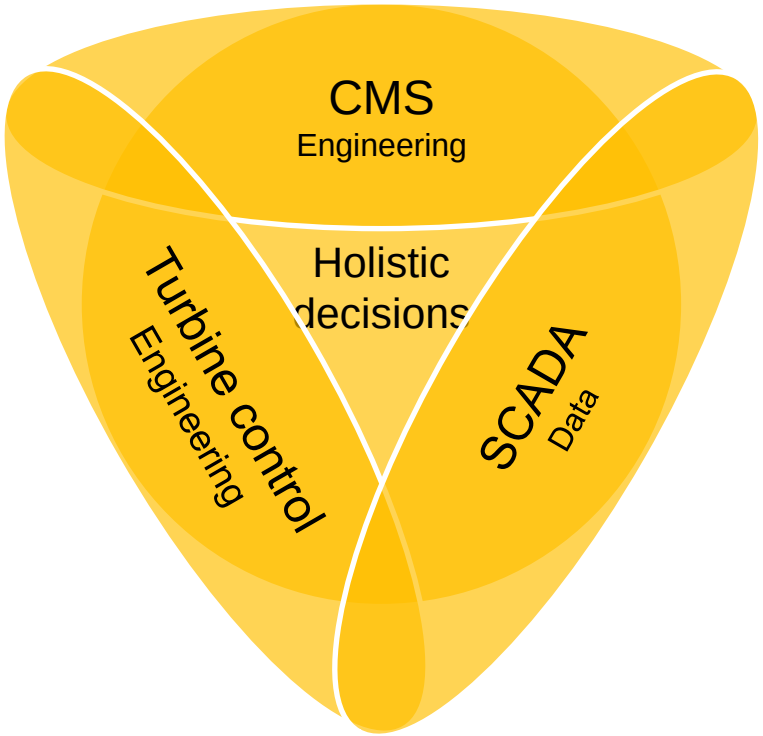
Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

6. Joined up SCADA/ control/CM
5. Demonstration of maintenance procedures
4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

6. Joined up SCADA/control/CM



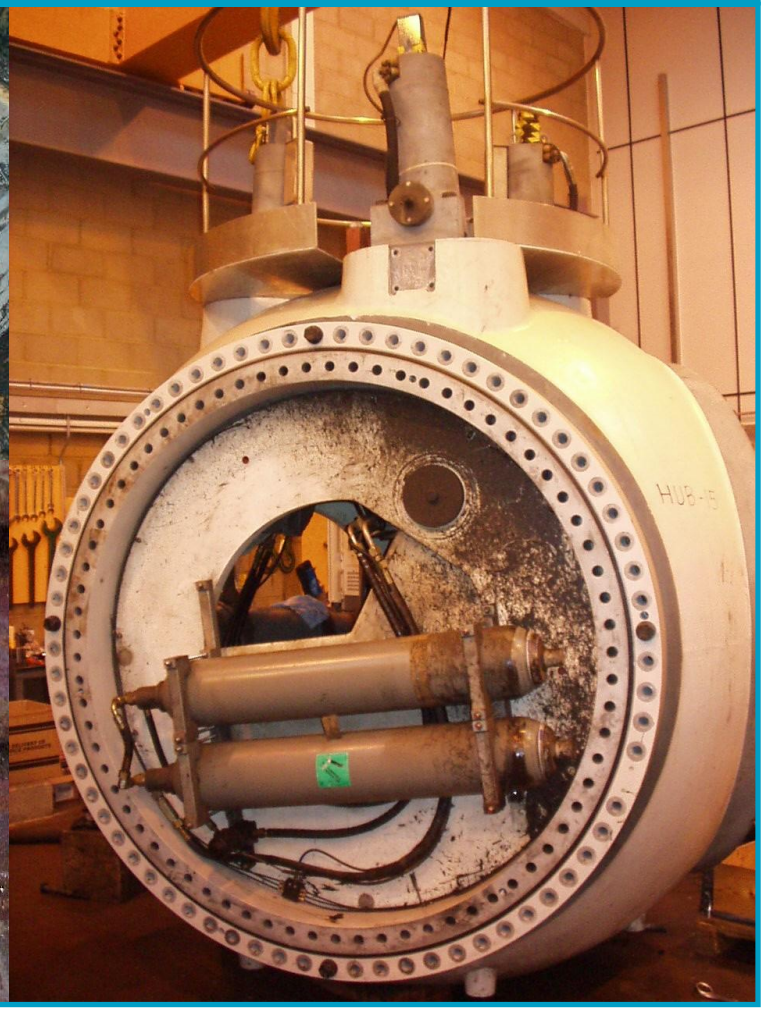
Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

7. Feedback from site
6. Joined up SCADA/ control/CM
5. Demonstration of maintenance procedures
4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

7. Feedback from site



Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

8. Useful, accurate data
7. Feedback from site
6. Joined up SCADA/ control/CM
5. Demonstration of maintenance procedures
4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

8. Useful, accurate data

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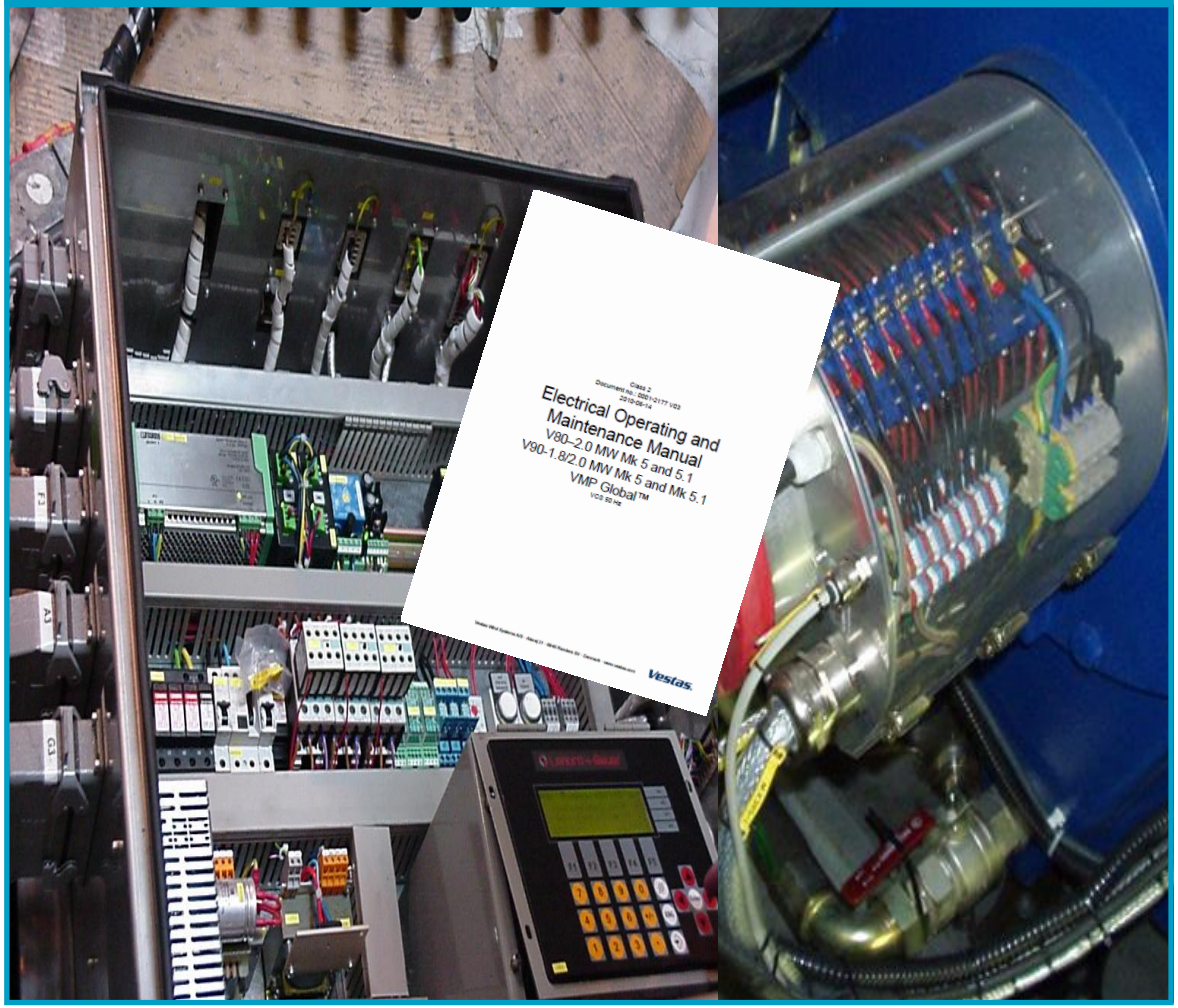
Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

9. Fix first time approach
8. Useful, accurate data
7. Feedback from site
6. Joined up SCADA/ control/CM
5. Demonstration of maintenance procedures
4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

9. Fix first time approach



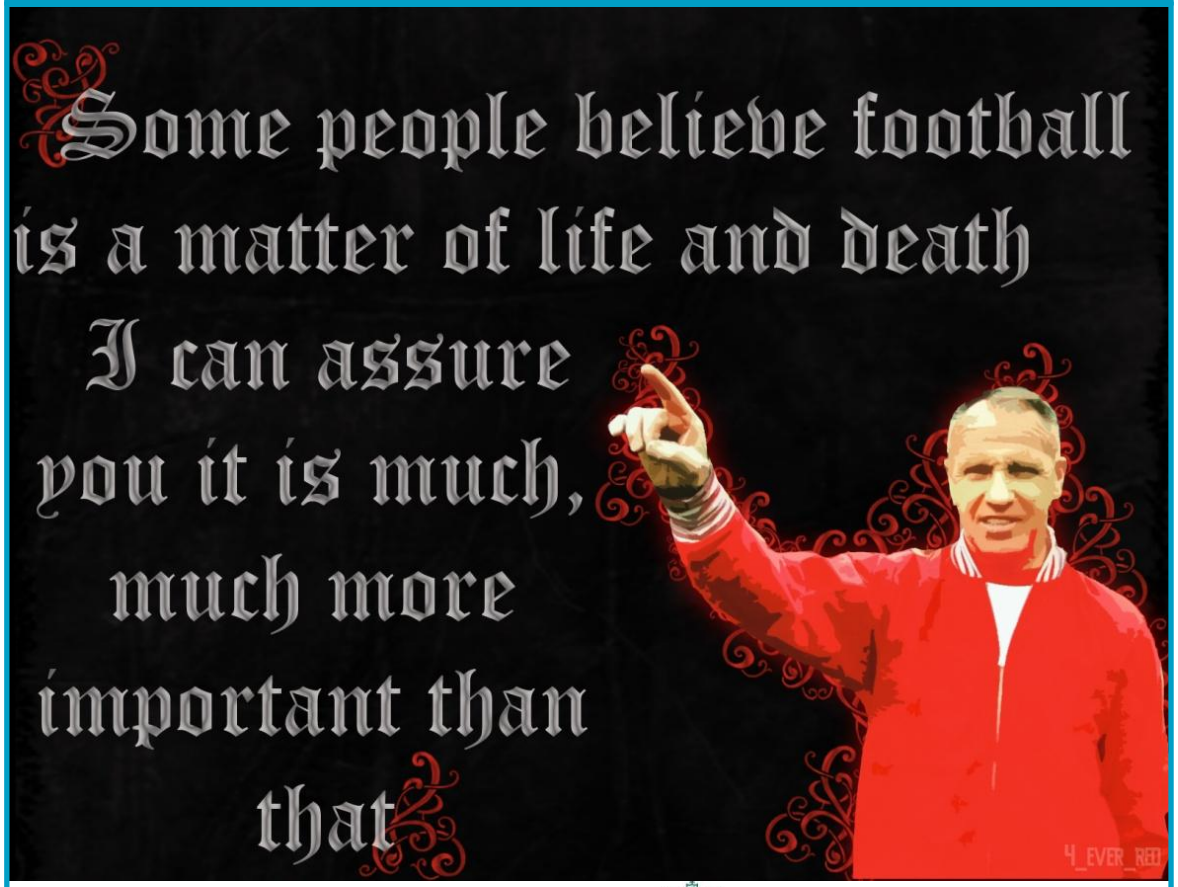
Reliability centred approach

Important ingredients of reliability centred approach

10 Steps to success

10. Reliability champion
9. Fix first time approach
8. Useful, accurate data
7. Feedback from site
6. Joined up SCADA/ control/CM
5. Demonstration of maintenance procedures
4. Test and verification
3. Component reliability reviews
2. ‘Rules of thumb’
1. Reliability and OPEX budgets (and model)

10. Reliability champion



Bill Shankly, Liverpool Football Club

Reliability centred approach during wind turbine development

Important ingredients of reliability centred approach

Beautiful, happy offshore wind farms...

... are born in messy places