WS8-Method for Evaluating Reliability of Tidal Stream Devices (TSD)

Prof. Peter Tavner
Energy Group

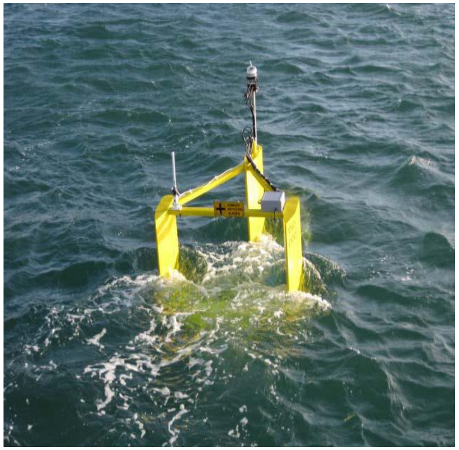
Work of:
PhD student Tatiana M. Delorm
MSc student Donatell Zappala

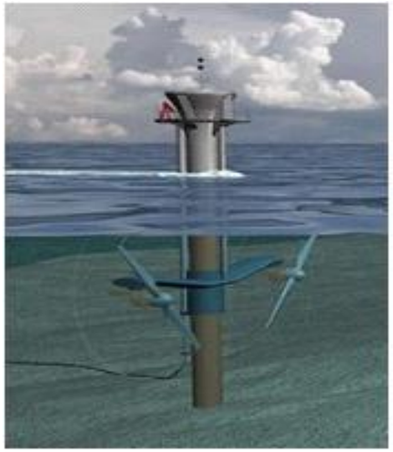
"*When one recognises how much the sum of our ignorance exceeds that of our knowledge, one is less likely to draw rapid conclusions.*"
Louis de Broglie

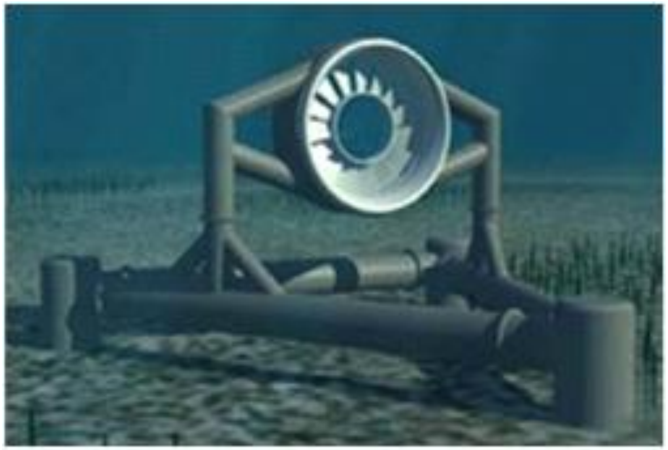
Durham University
School of Engineering and Computing Sciences

21st century Tidal Stream Devices

- >50 TSD technologies around the world, few will be viable;
- TSDs can be horizontal or vertical turbines or oscillating hydrofoils;
- Which are the most reliable architectures?







Durham University
School of Engineering and Computing Sciences

Problems Evaluating TSD Reliability

- Data not in public domain;
- TSDs incorporate both structural and machinery components;
- Equipment definition, particularly for auxiliaries, only available in generic terms;
- In absence of in-service reliability data it has been impossible for developers to evaluate prospective technologies;
- Need a system-reliability method to evaluate different architectures;
- To determine which is potentially most reliable.

Durham University
School of Engineering and Computing Sciences

4 off 1-1.5 MW TSDs Evaluated

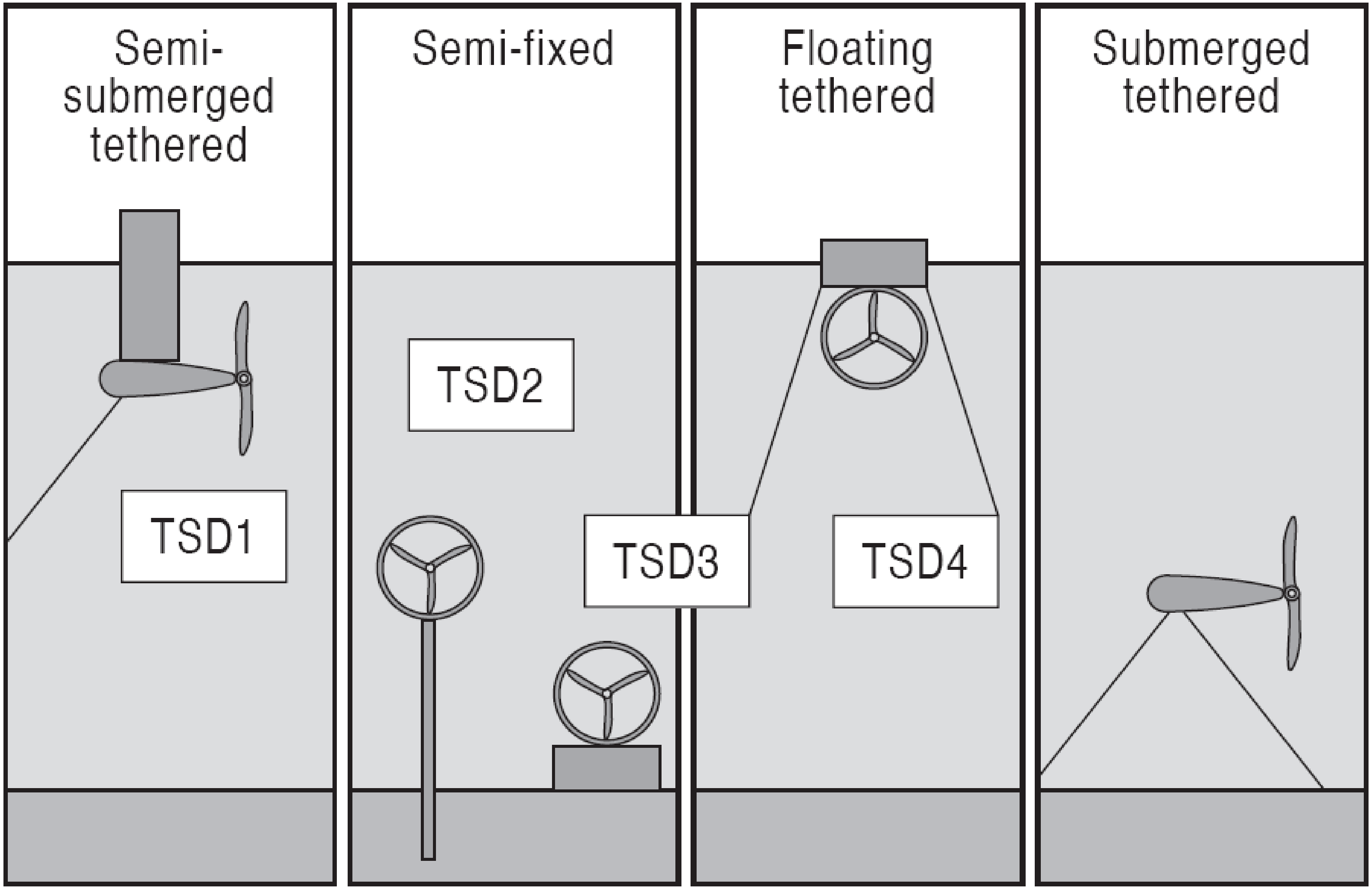


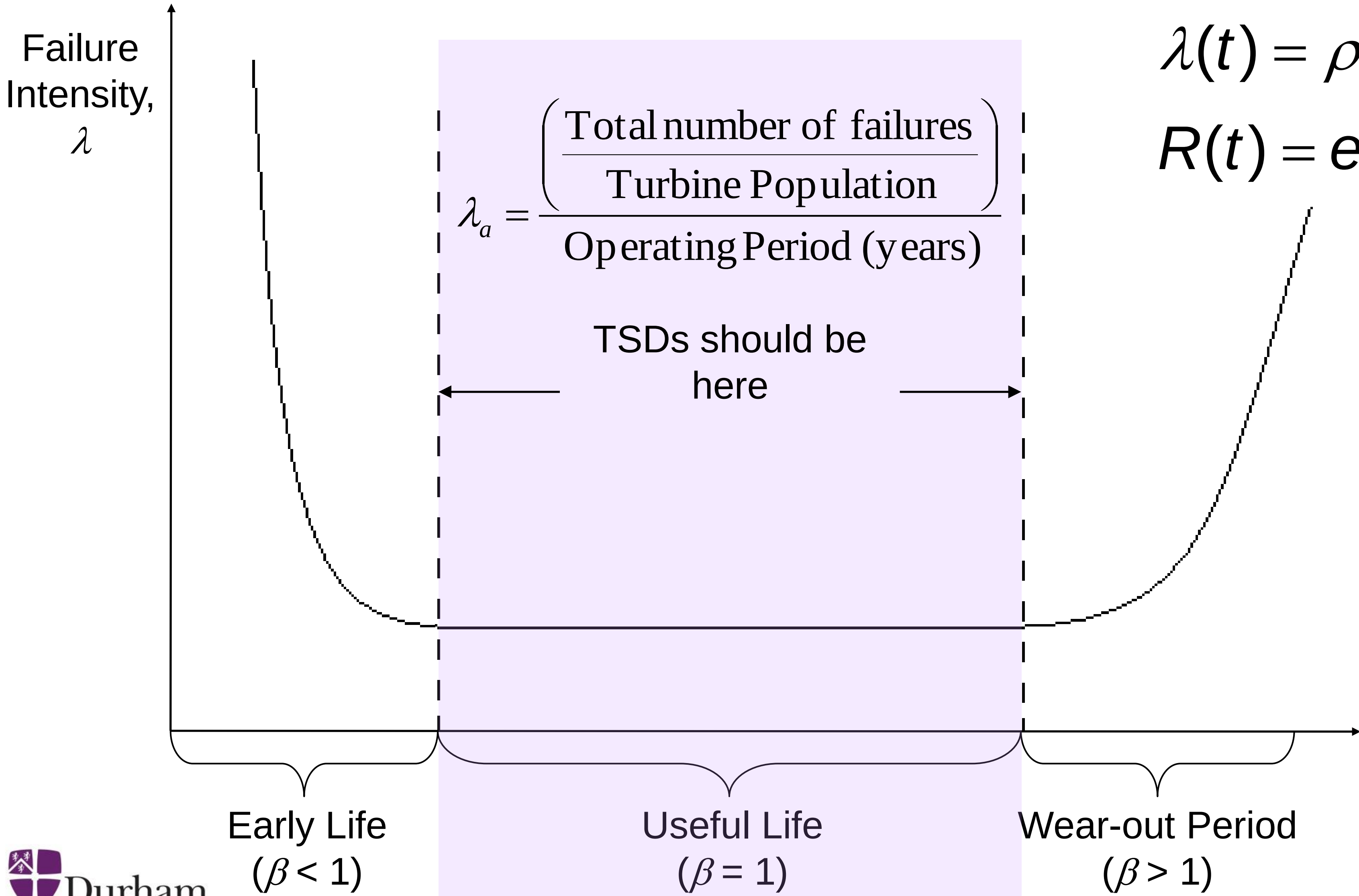
Figure 1: Horizontal axis TSDs [3]

Reliability Evaluation Method

- Top-down approach;
- Establish schematic diagram for each device, down to same sub-assembly level, showing interdependencies;
- Classify & name sub-assemblies using a robust method;
- Derive Reliability Block Diagram (FBD) from schematic;
- Populate RBD with reliability data from surrogate sources;
- From surrogate data establish lower & upper bound failure rates for each sub-assembly;
- Adjust surrogate surrogate lower & upper bound failure rates to tidal environment;
- Evaluate total device reliability assuming sub-assembly failures are random, ie bottom of bathtub;
- Complements bottom-up design approach in WS8.

Reliability Prediction Model

SUPERGEN MARINE



$$\lambda(t) = \rho\beta e^{-\beta t}$$

$$R(t) = e^{-\lambda t}$$

Durham University
School of Engineering and Computing Sciences

Surrogate Data Sources

- European onshore WT databases:
  - WMEP database, 14,400 turbine years data over 13 years;
  - LWK database, 5,800 turbine years over 14 years;
- Petrochemical industry database OREDA 1984-2002;
- Generic databases
  - NPRD-95
  - MIL-HDBK 217F
- Adjust data to represent tidal environment:

Table 1. Environments of Surrogate Data Sources used in the model

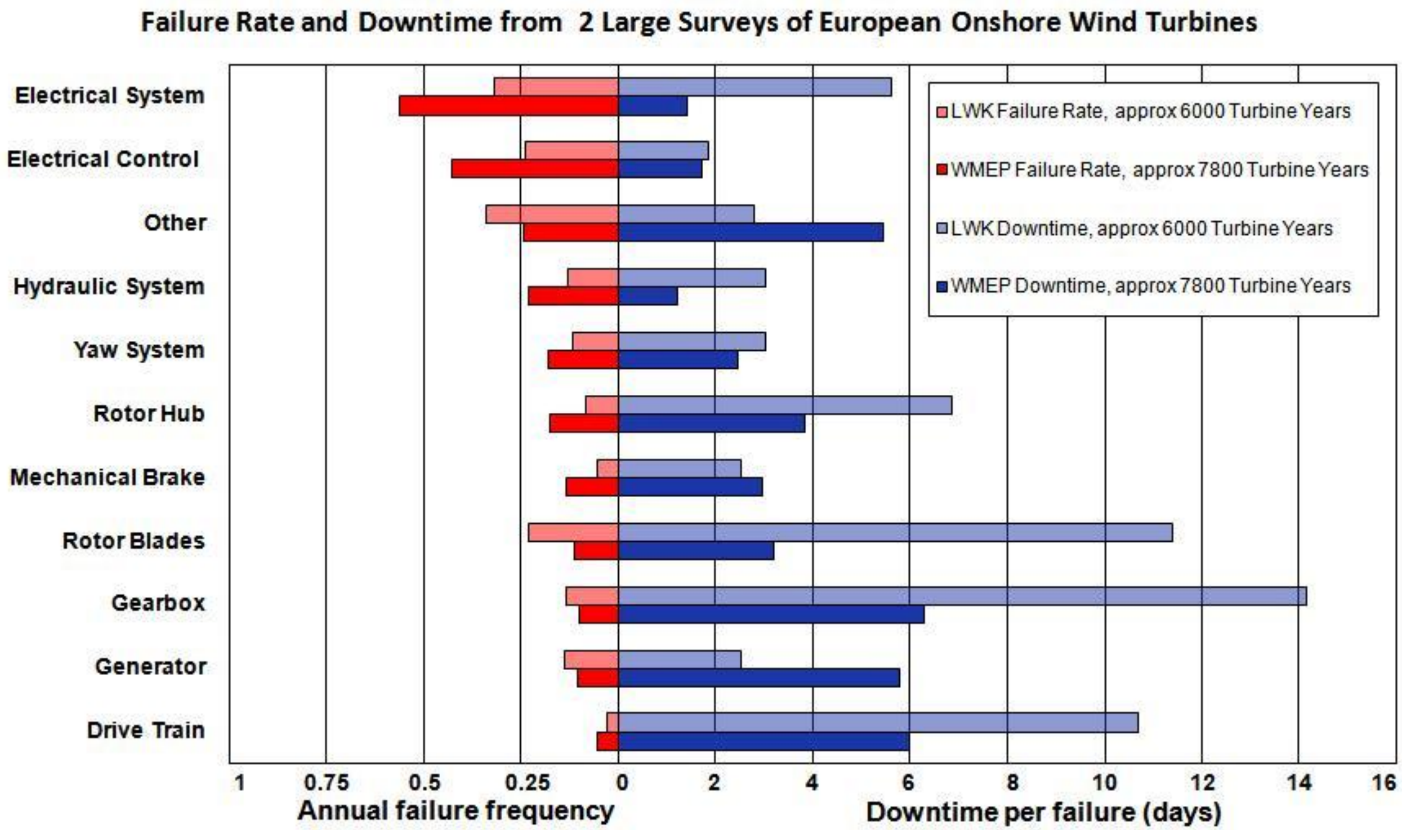
Surrogate Data Source	**Naval, Unsheltered: Severe Environment NU**	**Naval, Sheltered: Normal Environment NS**	**Ground, Fixed: Severe Environment GF**
LWK WMEP	-	-	X
OREDA	X	X	X
NPRD-95	X	X	X
MIL-HDBK217F	X	X	X

Most TSD sub-assemblies here

But some here

Durham University
School of Engineering and Computing Sciences

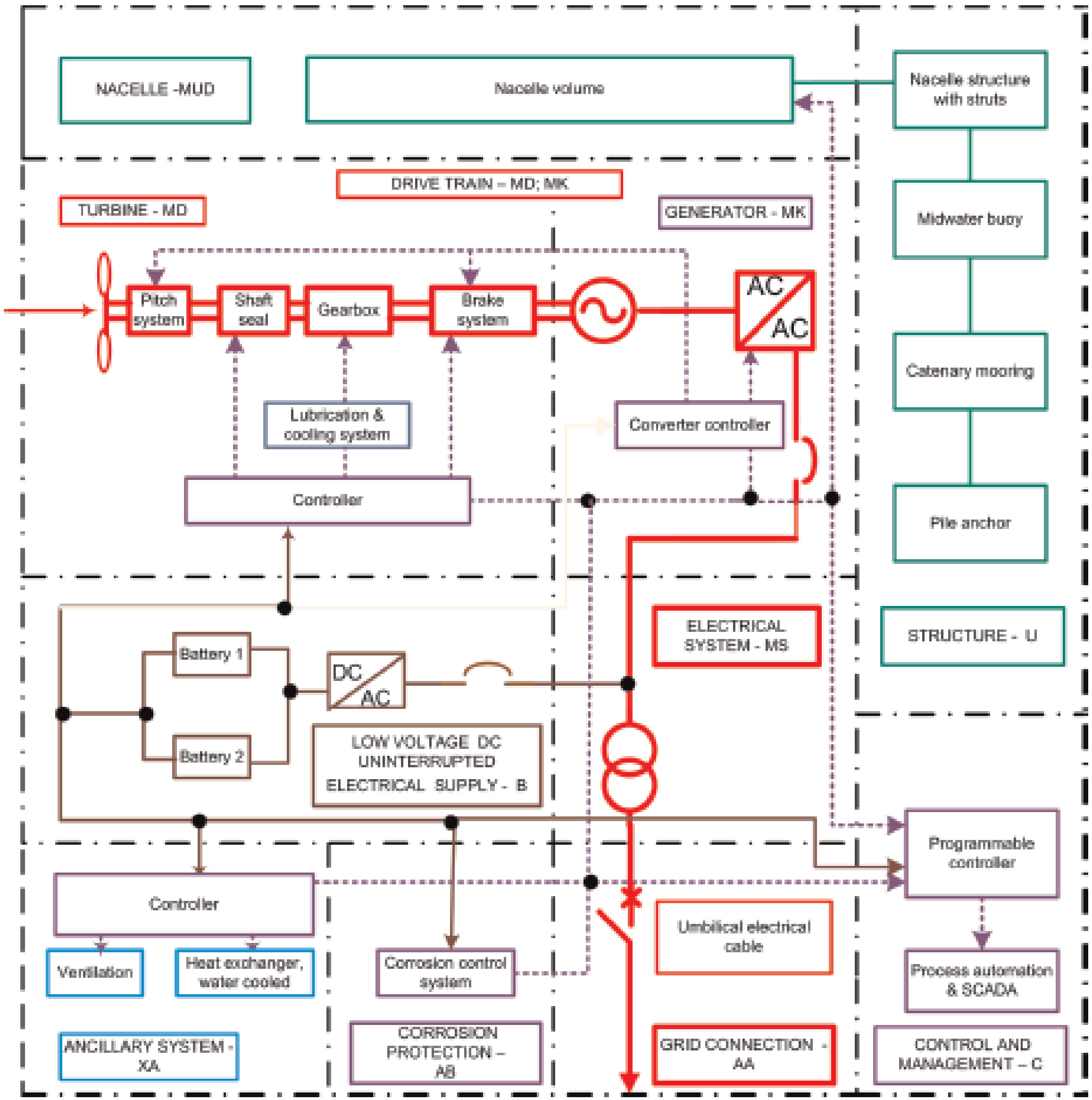
Typical Surrogate Data



Surrogate data is study backbone because no reliability data yet available for TSDs. Architectures and core technologies of wind turbines are similar to TSDs.

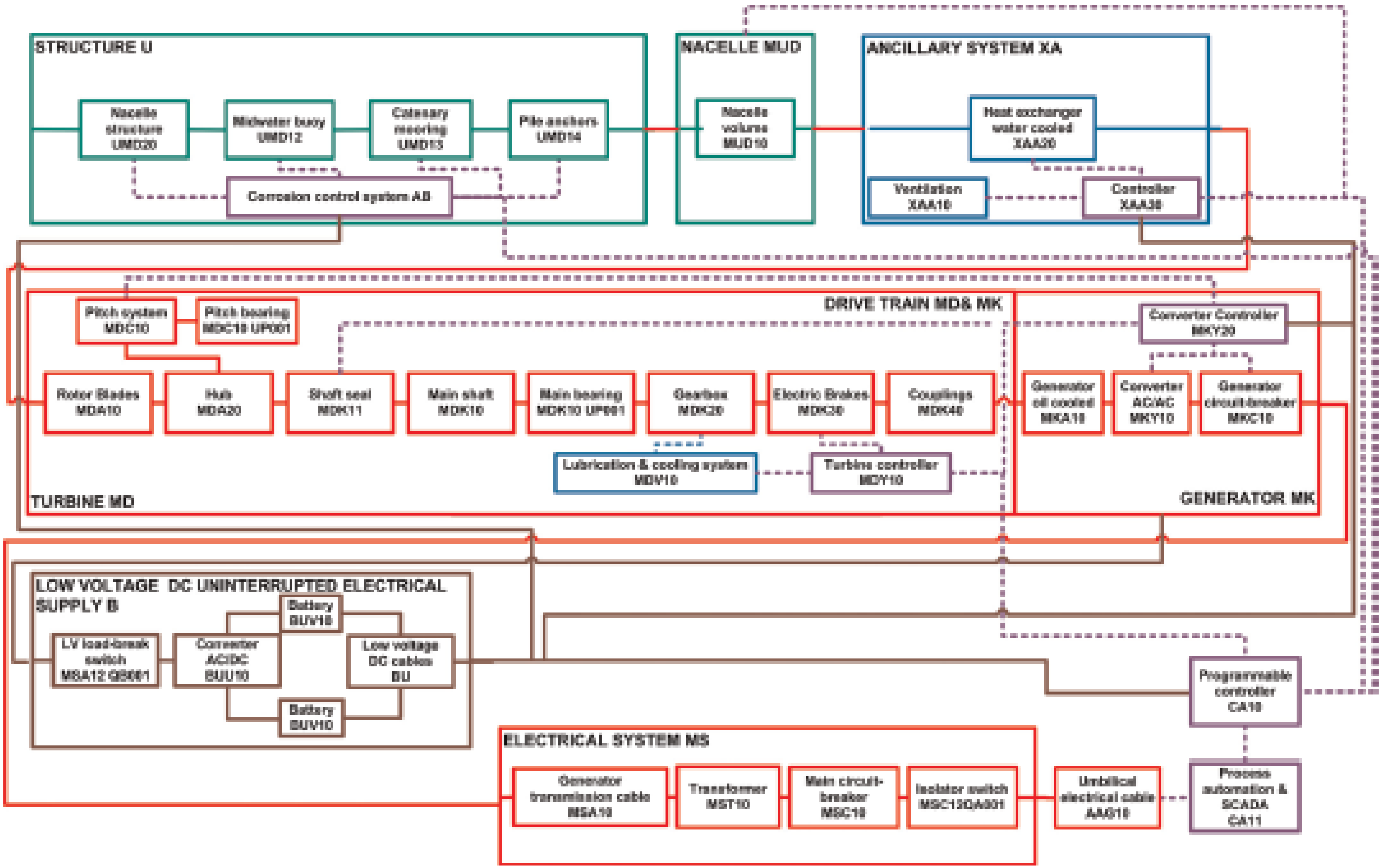
Durham University
School of Engineering and Computing Sciences

Schematic for TSD1



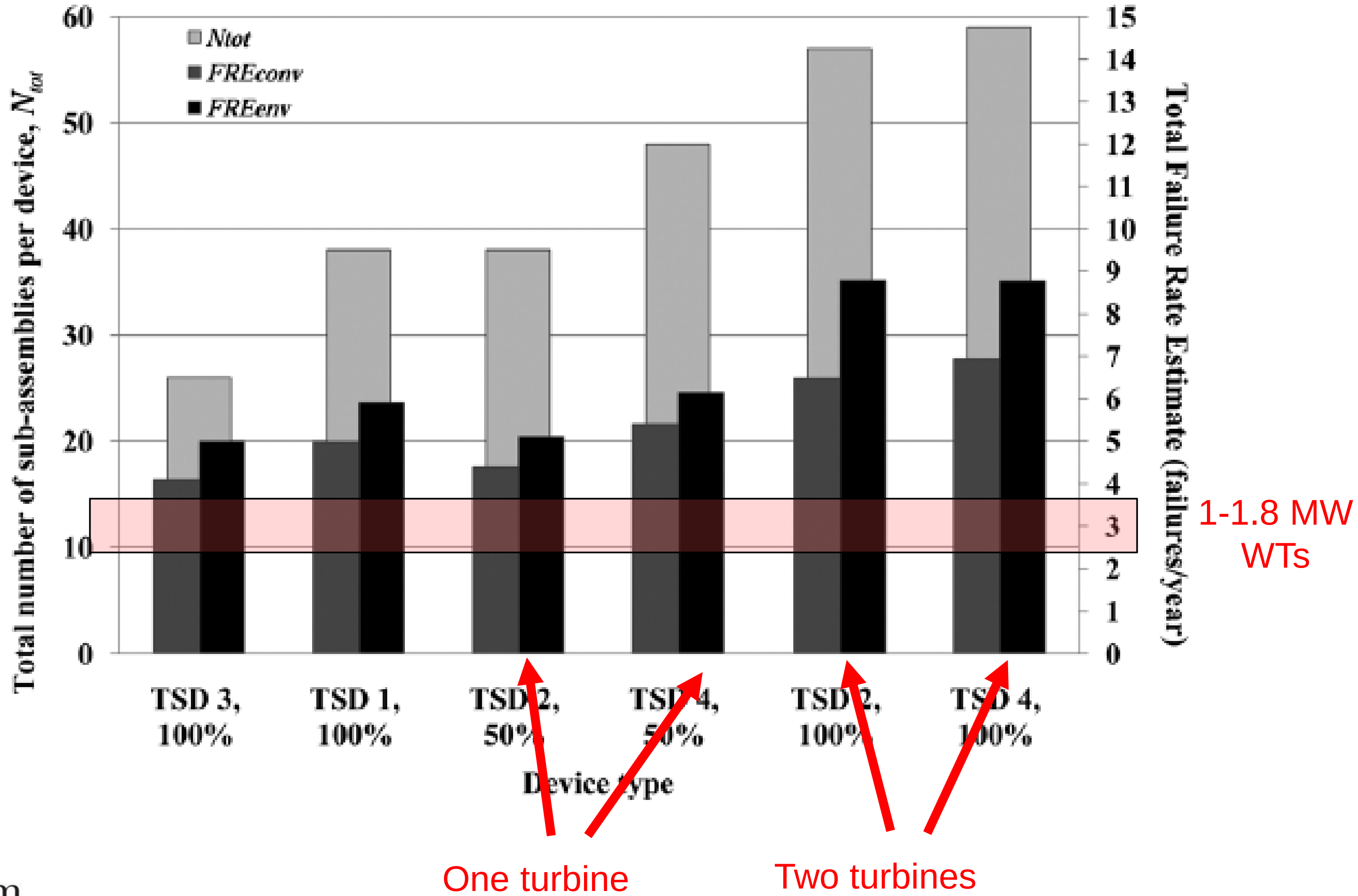
Durham University
School of Engineering and Computing Sciences

RBD for TSD1



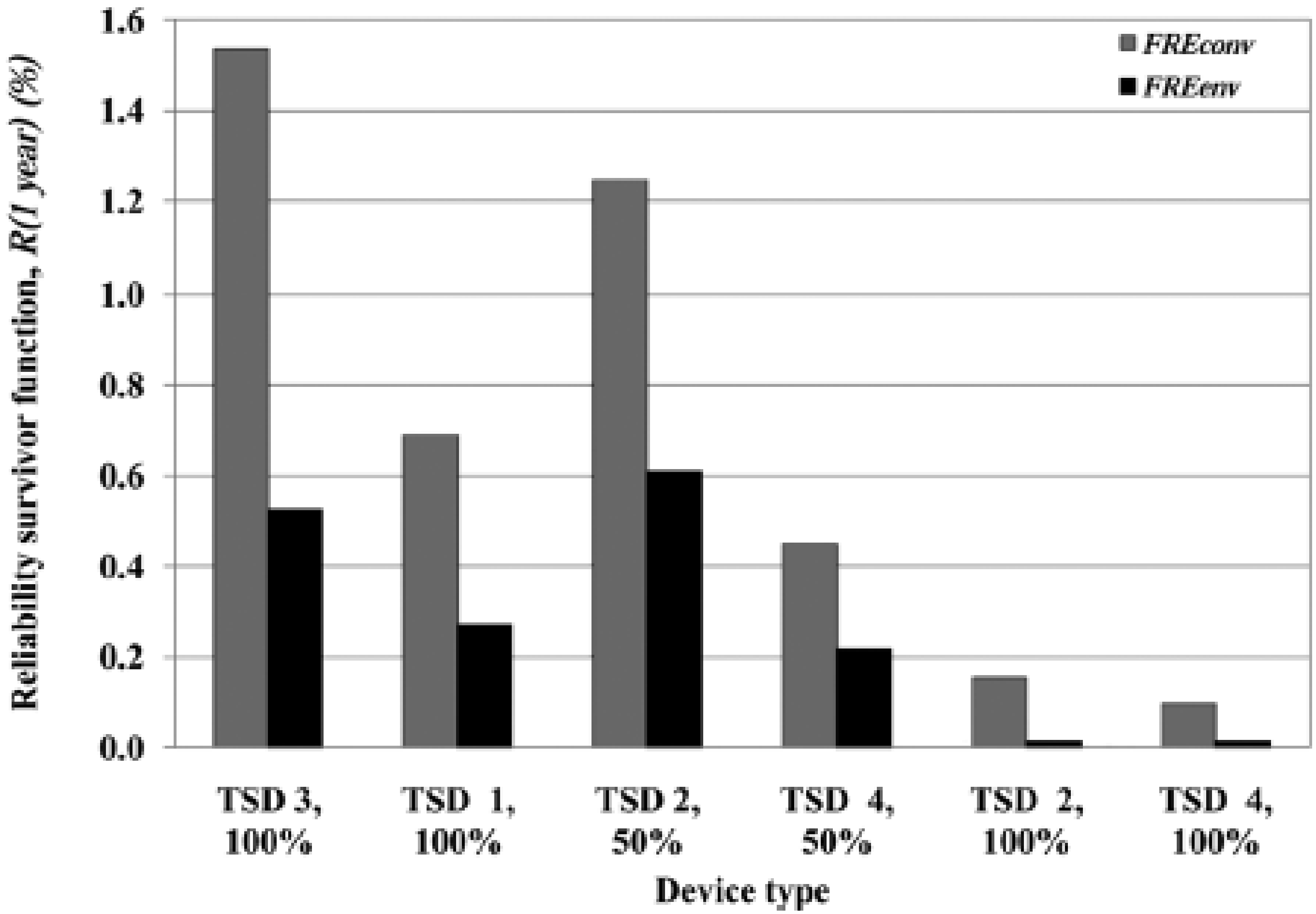
STRUCTURE U
Nacelle structure UMD20
Midwater buoy UMD12
Catenary mooring UMD13
Pile anchors UMD14
Corrosion control system AB
NACELLE MUD
Nacelle volume MUD10
ANCILLARY SYSTEM XA
Heat exchanger water cooled XAA20
Ventilation XAA10
Controller XAA30
DRIVE TRAIN MD& MK
Pitch system MDC10
Pitch bearing MDC10 UP001
Converter Controller MKY20
Rotor Blades MDA10
Hub MDA20
Shaft seal MDK11
Main shaft MDK10
Main bearing MDK10 UP001
Gearbox MDK20
Electric Brakes MDK30
Couplings MDK40
Generator oil cooled MKA10
Converter AC/AC MKY10
Generator circuit-breaker MKC10
Lubrication & cooling system MDV10
Turbine controller MDY10
TURBINE MD
GENERATOR MK
LOW VOLTAGE DC UNINTERRUPTED ELECTRICAL SUPPLY B
Battery BUV10
LV load-break switch MSA12 QB001
Converter AC/DC BUU10
Low voltage DC cables BU
Battery BUV10
Programmable controller CA10
ELECTRICAL SYSTEM MS
Generator transmission cable MSA10
Transformer MST10
Main circuit-breaker MSC10
Isolator switch MSC10QA001
Umbilical electrical cable AAG10
Process automation & SCADA CA11

Predicted 1-1.5 MW TSDs Failure Rates



Durham University
School of Engineering and Computing Sciences

Predicted Survivors after 1 yr Service



Durham University
School of Engineering and Computing Sciences

Conclusions

SUPERGEN MARINE

- Methodology for analysing TSD reliability devised;
- Simple architectures give best reliability results;
- Preliminary failure rates are high, survivor rates low;
- Sub-assembly failure rates similar to bottom-up predictions;
- Failure rates need drastic reduction;
- Analysis shows sub-assemblies where effort needed;
- 1 year TSD operation as non-repairable system with no maintenance will give unacceptable survivor rates;
- Lower failure rates & better access will achieve better survivor rates;
- Array size and redundancy will raise TSD reliability;
- Perhaps moorable, detachable devices have potential?

Durham University
School of Engineering and Computing Sciences