Reliability & Availability of Wind Turbine Electrical & Electronic Components

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"One has to consider causes rather than symptoms of undesirable events and avoid uncritical attitudes."
Prof Dr Alessandro Birolini

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Summary of Reliawind

- EU funded FP7 R&D project
- €7.7M total funding
- €5.5M EU funding
- 10 organisations involved
- 3 years

Aims:

- Improve general understanding of wind turbine and farm reliability
- Develop reliability models specific to wind turbines

- Increase MTBF
- Decrease MTTR
- Increase Availability
- Decrease Cost of Energy

Important Onshore → Critical Offshore

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Summary of Reliawind

Partners:

1. Gamesa
2. Ecotecnia
3. LM Glasfiber
4. Hansen Transmissions
5. ABB Machines & Drives
6. SKF UK
7. Garrad Hassan
8. RELEX
9. Durham University
10. SZTAKI

Wind Turbine Manufacturers (1–2)

Component Manufacturers (3–7)

Expert Knowledge (7–10)

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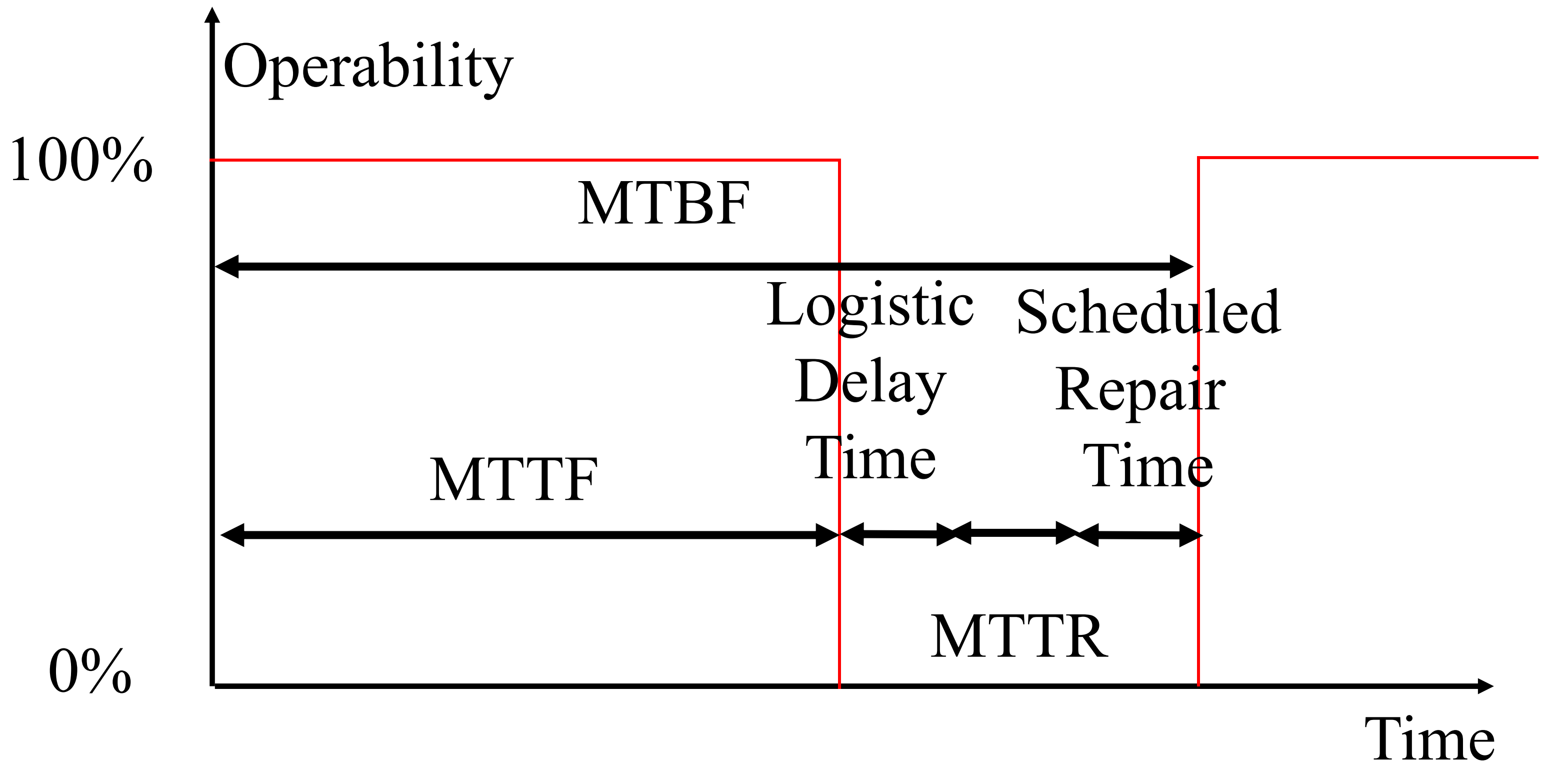
Availability, Operator



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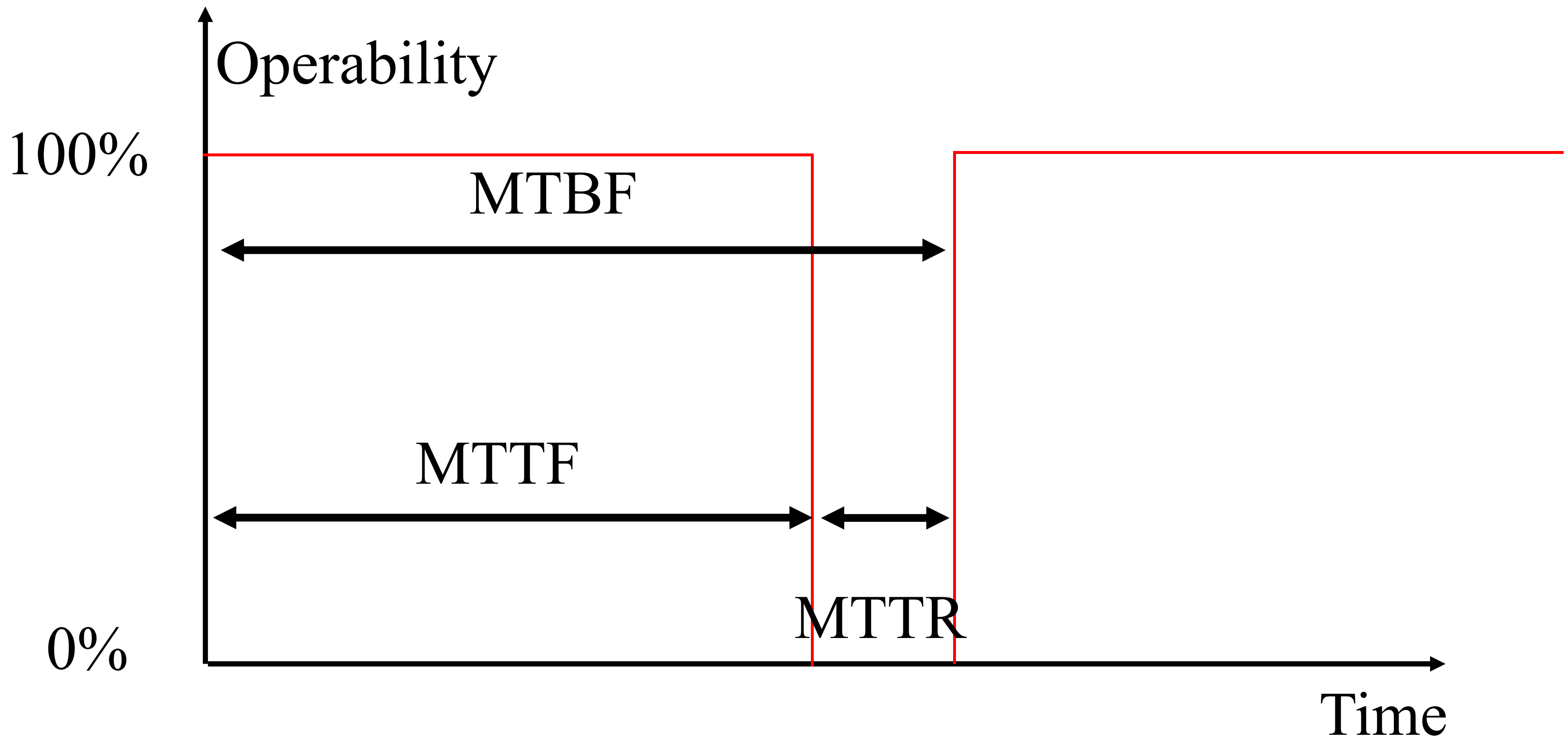
SUPERGEN WIND

ReliaWind

Availability, Manufacturer



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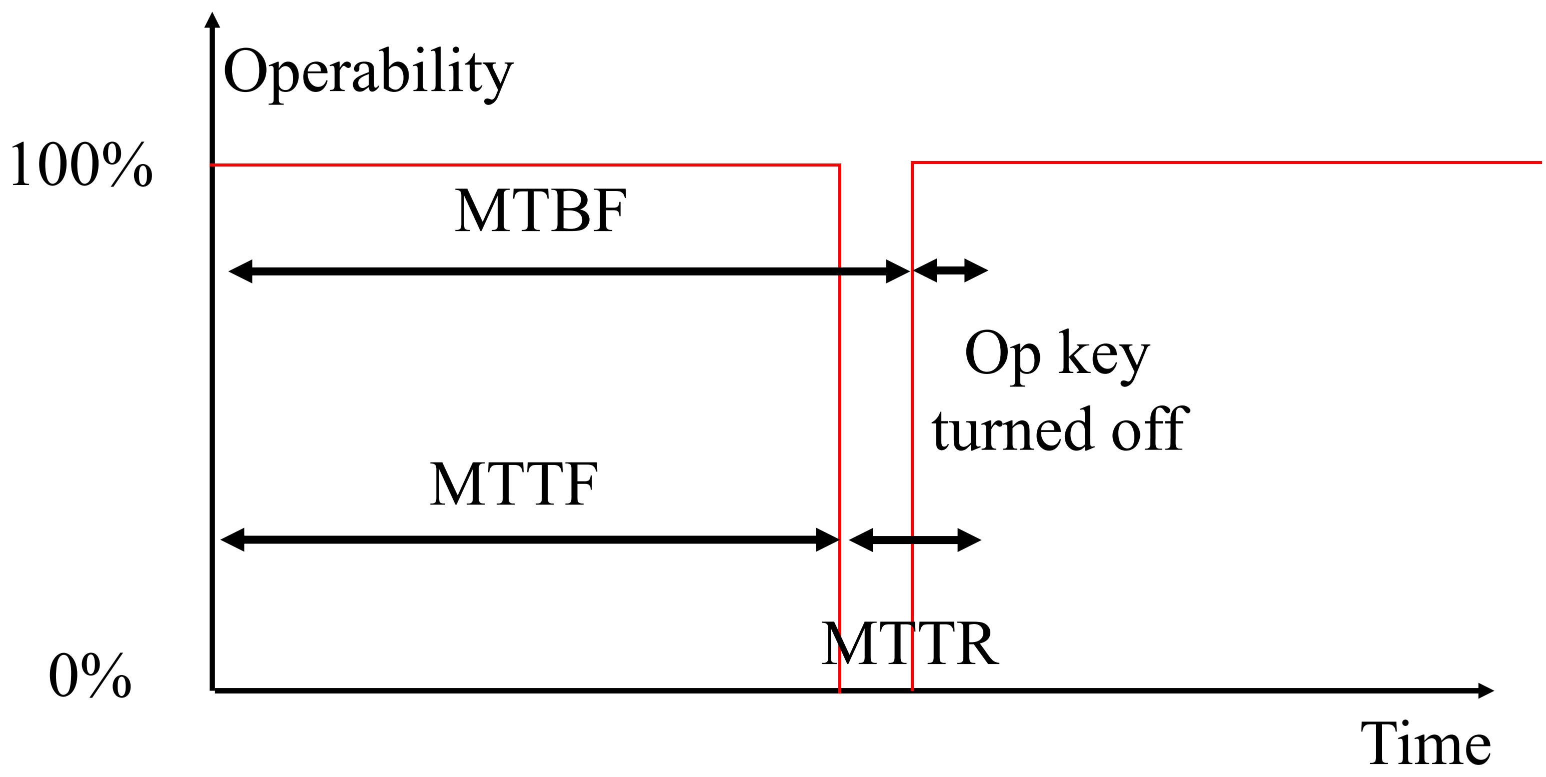
Availability, Manufacturer?



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Availability & Reliability

- Mean Time To Failure, *MTTF*
- Mean Time to Repair, or downtime *MTTR*
- Logistic Delay Time *LDT*
- Mean Time Between Failures,

$$MTTF \approx MTBF$$

$$MTBF = MTTF + MTTR + LDT$$

- Failure rate, λ $\lambda = 1/MTBF$
- Repair rate, μ $\mu = 1/MTTR$

$$MTBF \approx MTTF + MTTR = 1/\lambda + 1/\mu$$

- **Manufacturer's or Inherent Availability,**

$$A_i = (MTBF - MTTR)/MTBF = 1 - (\lambda/\mu)$$

- **Operational or Technical Availability,**

$$A_o = MTTF/MTBF < 1 - (\lambda/\mu)$$

- Typical UK values
  - Operational or Technical Availability 97%,
  - Manufacturer's or Inherent Availability 98%

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Cost of Energy, *COE*

- *COE, £/kWh=*

  *O&M+ {[(ICC*FCR) + LRC]/AEPnet}*
  - *O&M*=Cost of Operations & Maintenance, £
  - *ICC*=Initial Capital Cost, £
  - *FCR*=Fixed Charge Rate, interest, %
  - *LRC*=Levelised Cost of Replacement, replacing unavailable generation, £
  - *AEP*=Annualised Energy Production, kWh
- *COE , £/kWh =*

  $O\&M(\lambda, 1/\mu) + \{[(ICC*FCR) + LRC(\lambda, 1/\mu)]/AEPnet(A(\mu, 1/\lambda)\}$

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Cost of Energy, *COE*

- Reduce failure rate, λ,
  Reliability MTBF, $1/\lambda$, increases and
  Availability, A, improves
- Increase repair rate, μ,
  Downtime MTTF, $1/\mu$, reduces, and
  Availability, A, improves
- Therefore reduces *COE*

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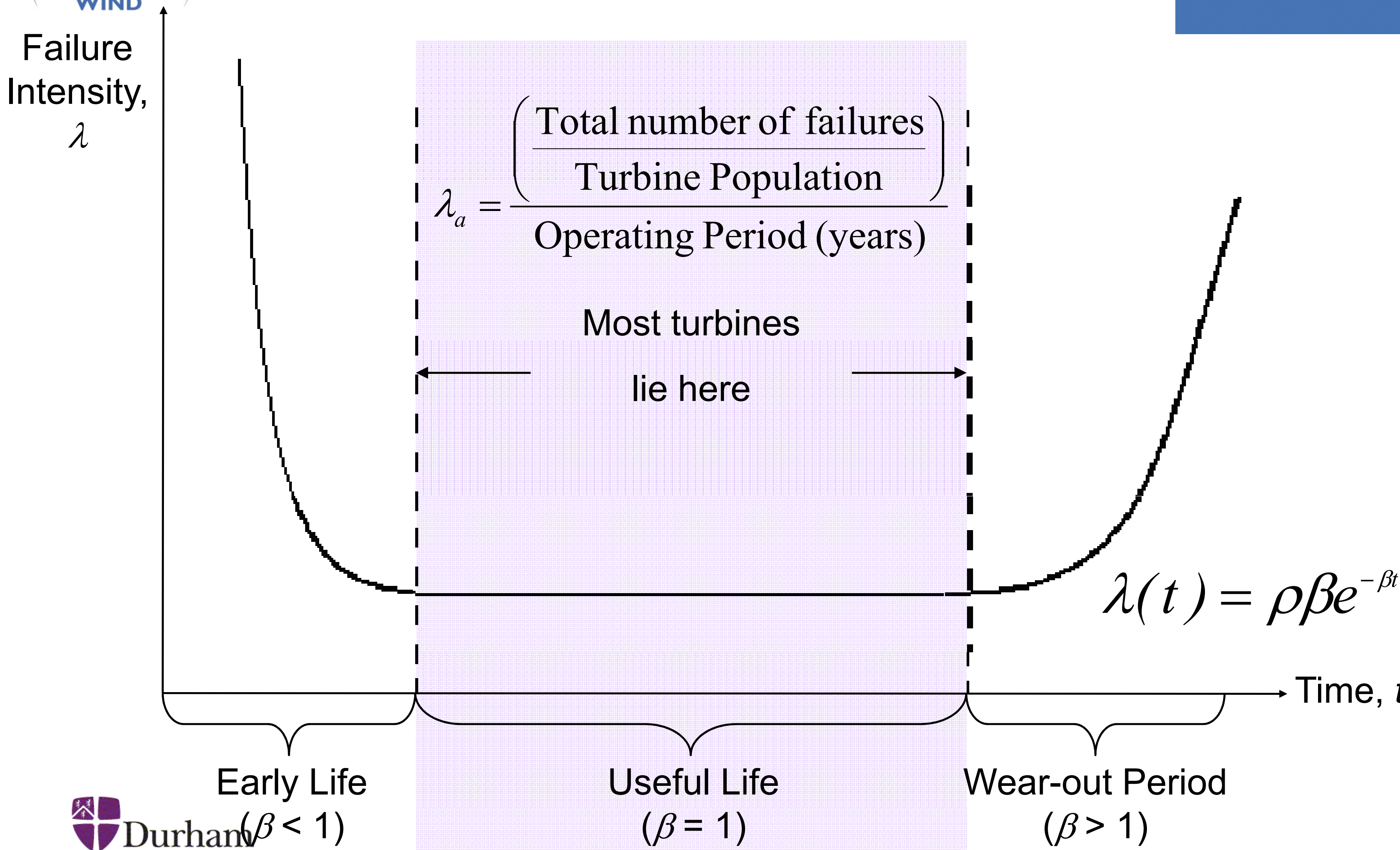
The Bathtub Curve



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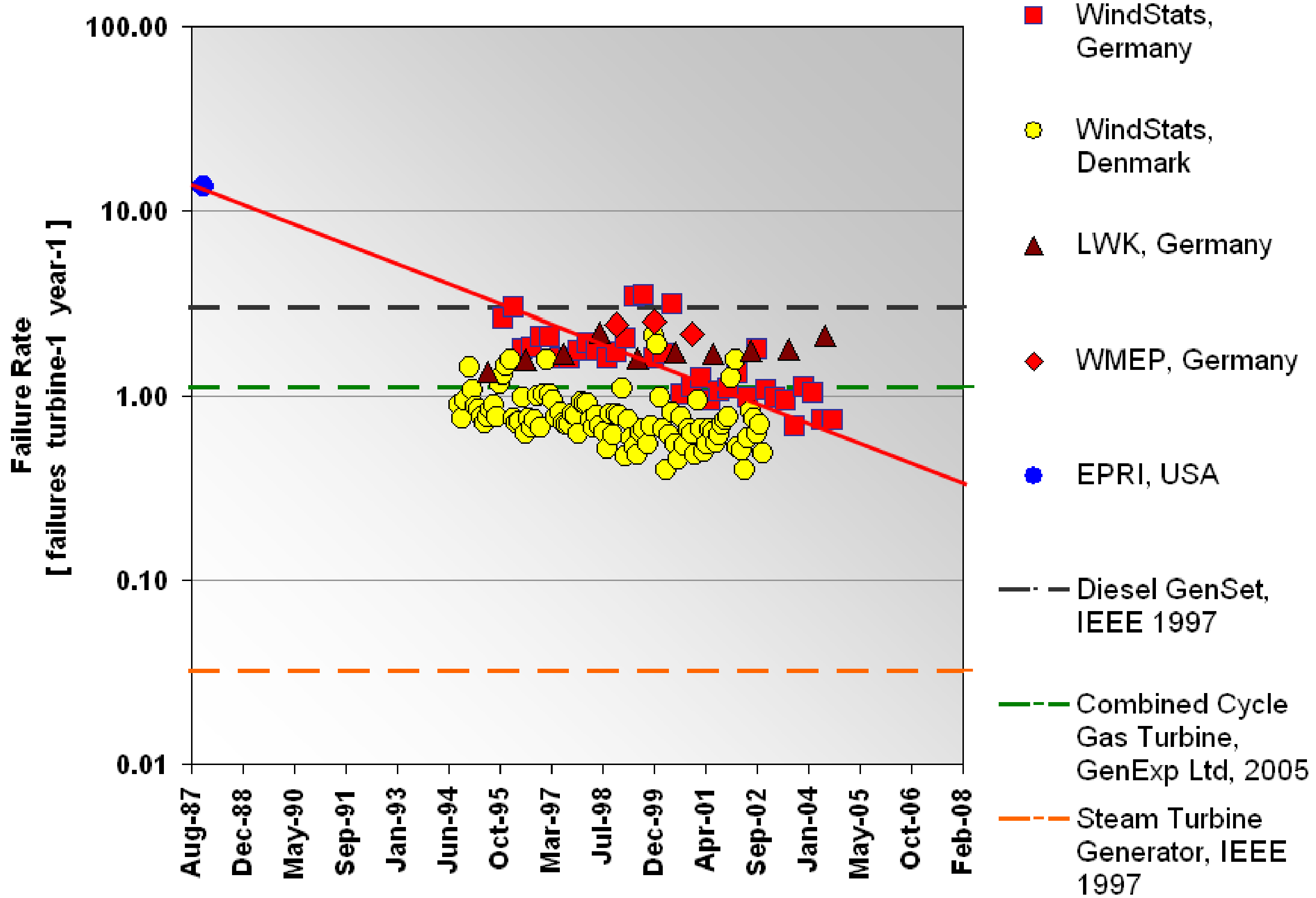
Trend in Turbine Failure Rates with time



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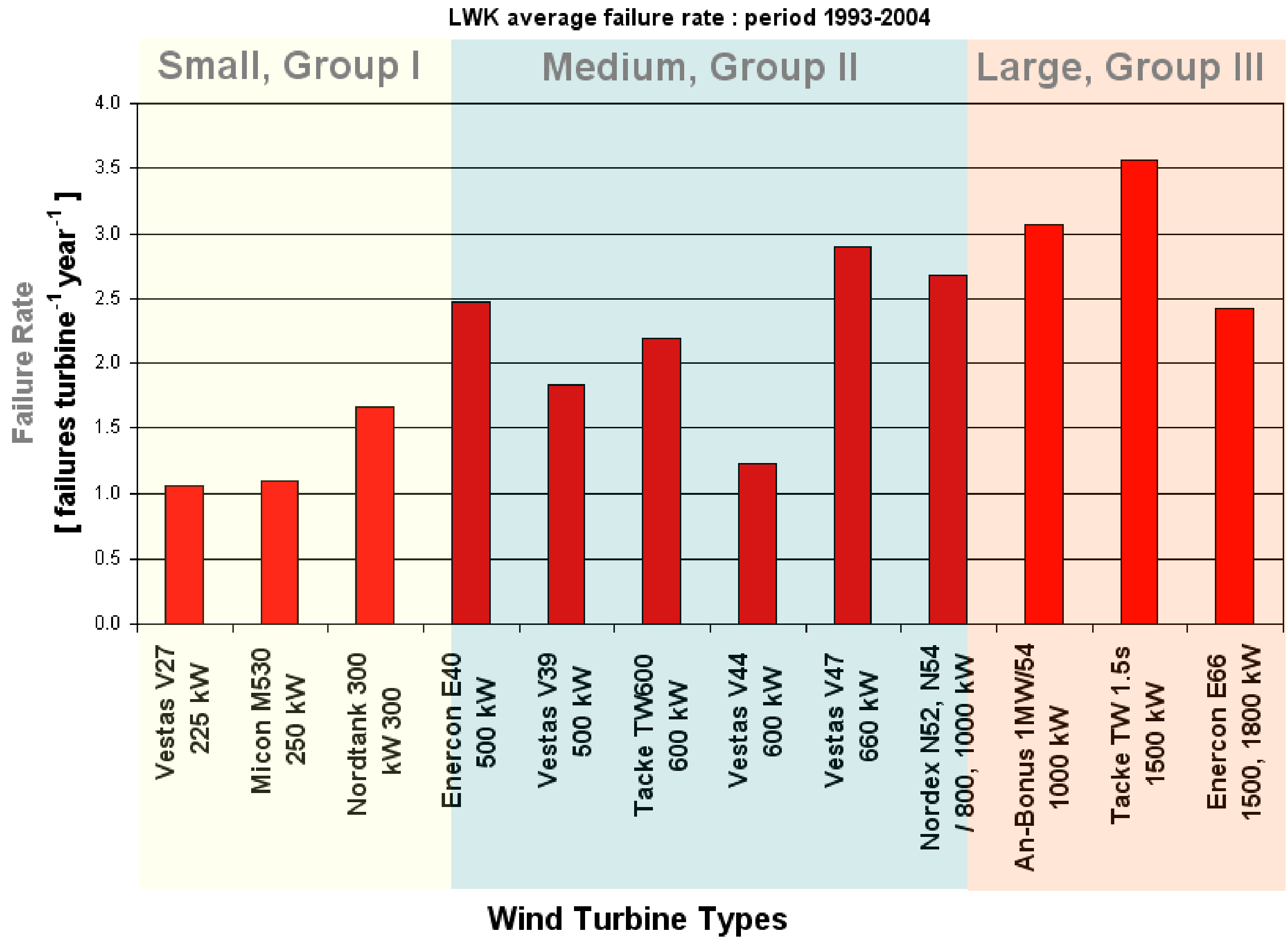
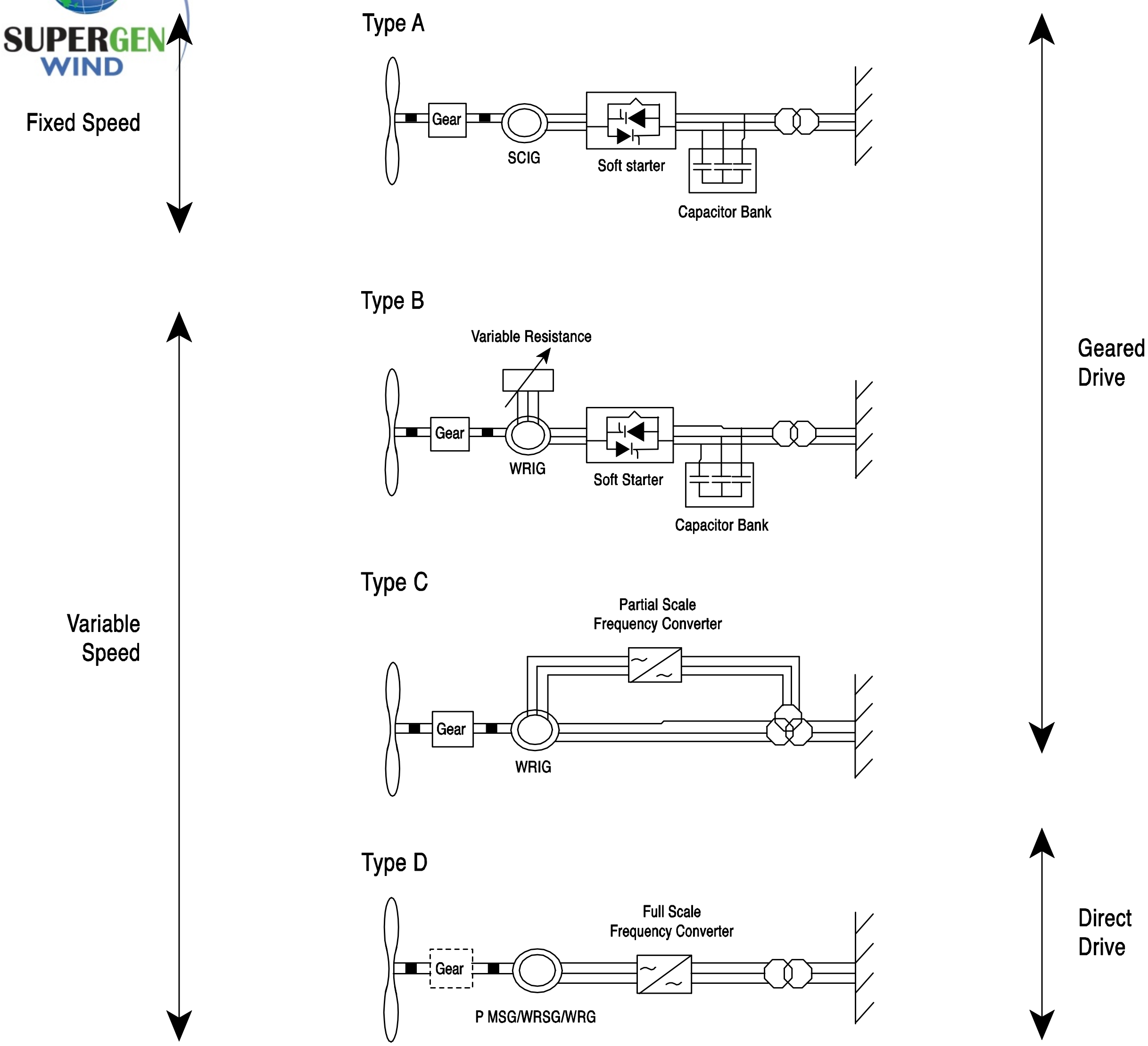
Reliability & Size, EU



Wind Turbine Configurations



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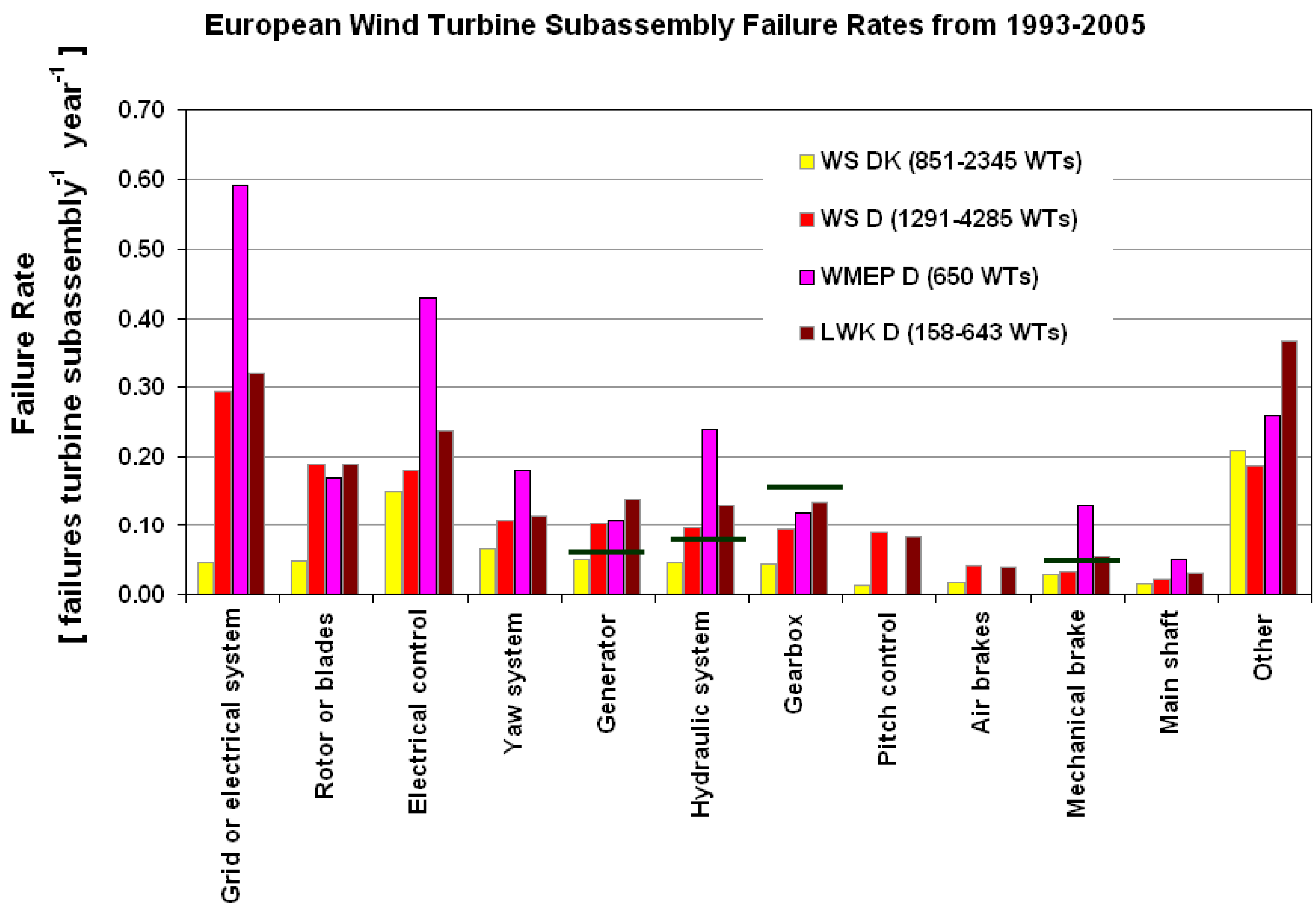
Reliability & Subassemblies , EU



Industrial Reliability figures

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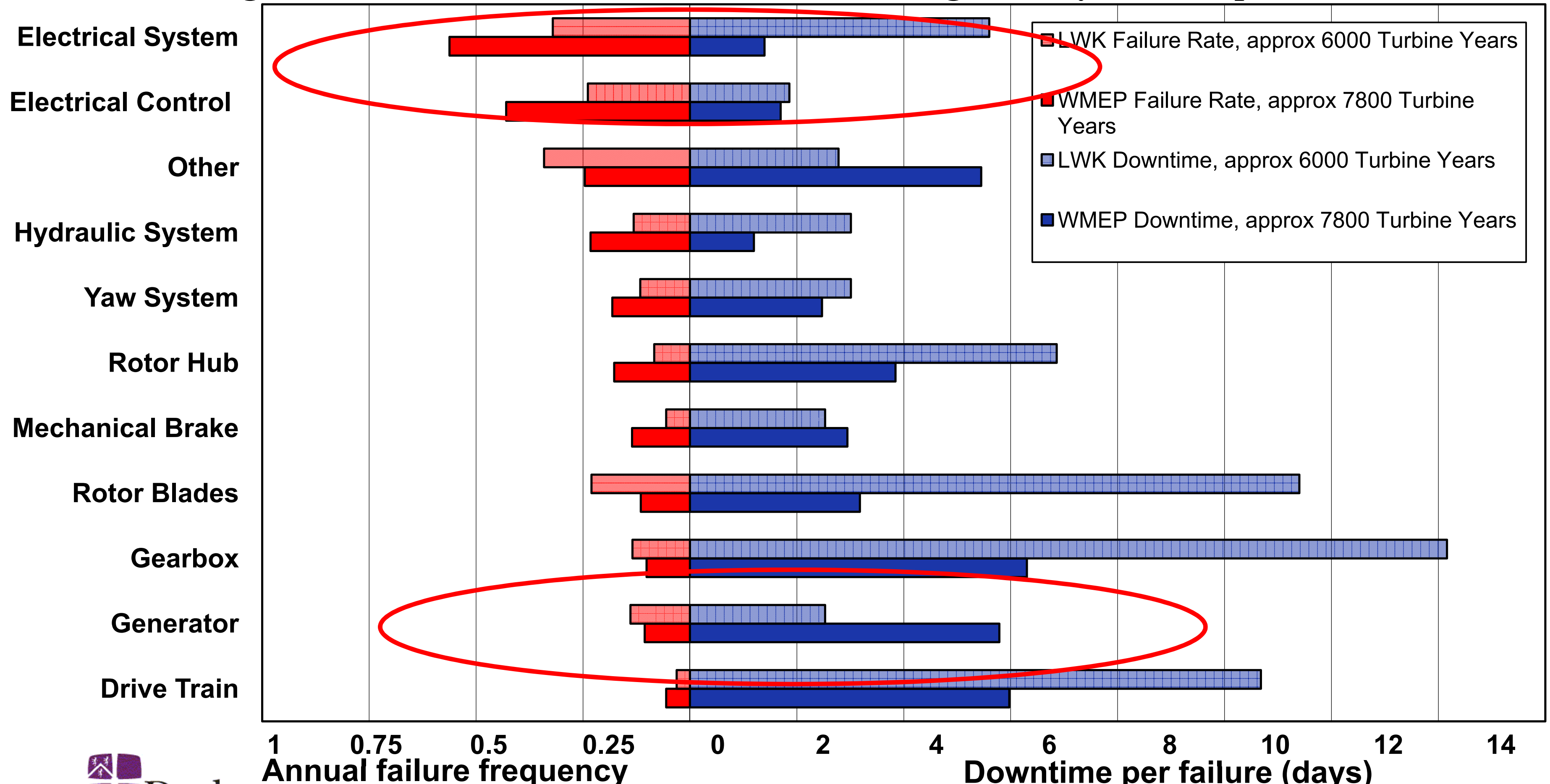
TU Delft Technische Universiteit Delft

Reliability & Downtime & Subassemblies, EU

ISET Pivot Diagram Failure Rate and Downtime from 2 Large Surveys of European Wind Turbines



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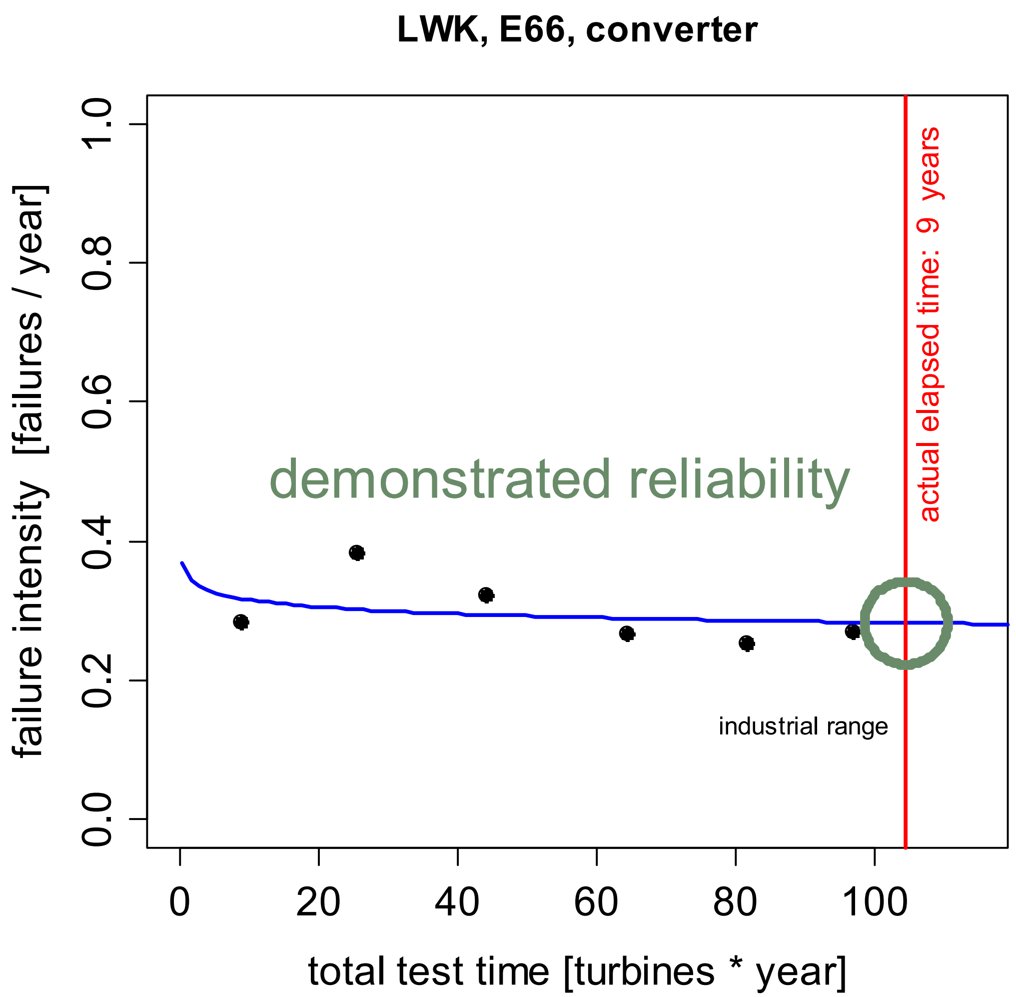
Reliability & Time, LWK



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Reliability & Time, LWK Generators

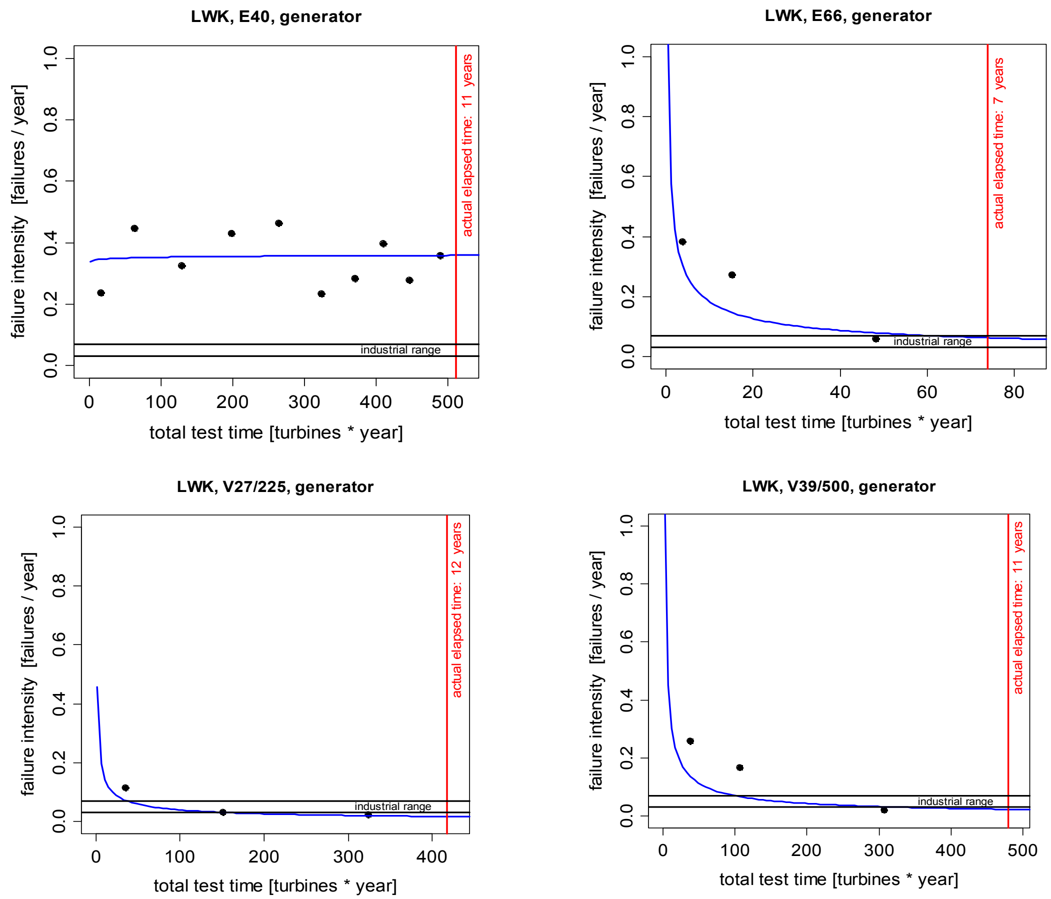

Figure 4.4: Variation between the failure rates of generator subassemblies, in the LWK population of German WTs, using the PLP model.
The upper two are low speed direct drive generators while the lower two are high speed indirect drive generators.

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Reliability & Time, LWK Gearboxes

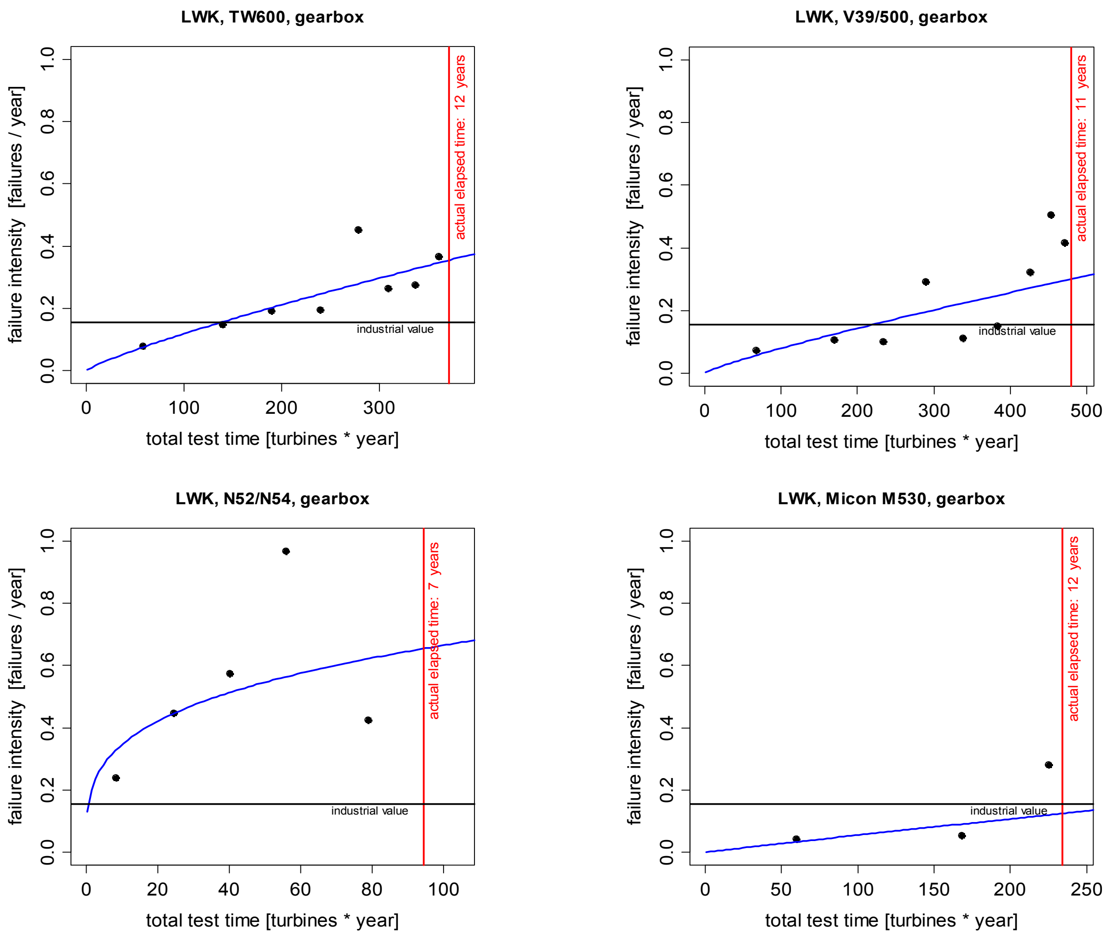

Figure 4.5: Variation between the failure rates of gearbox subassemblies, using the PLP model, in the LWK population of German WTs.

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Reliability & Time, LWK Electronics

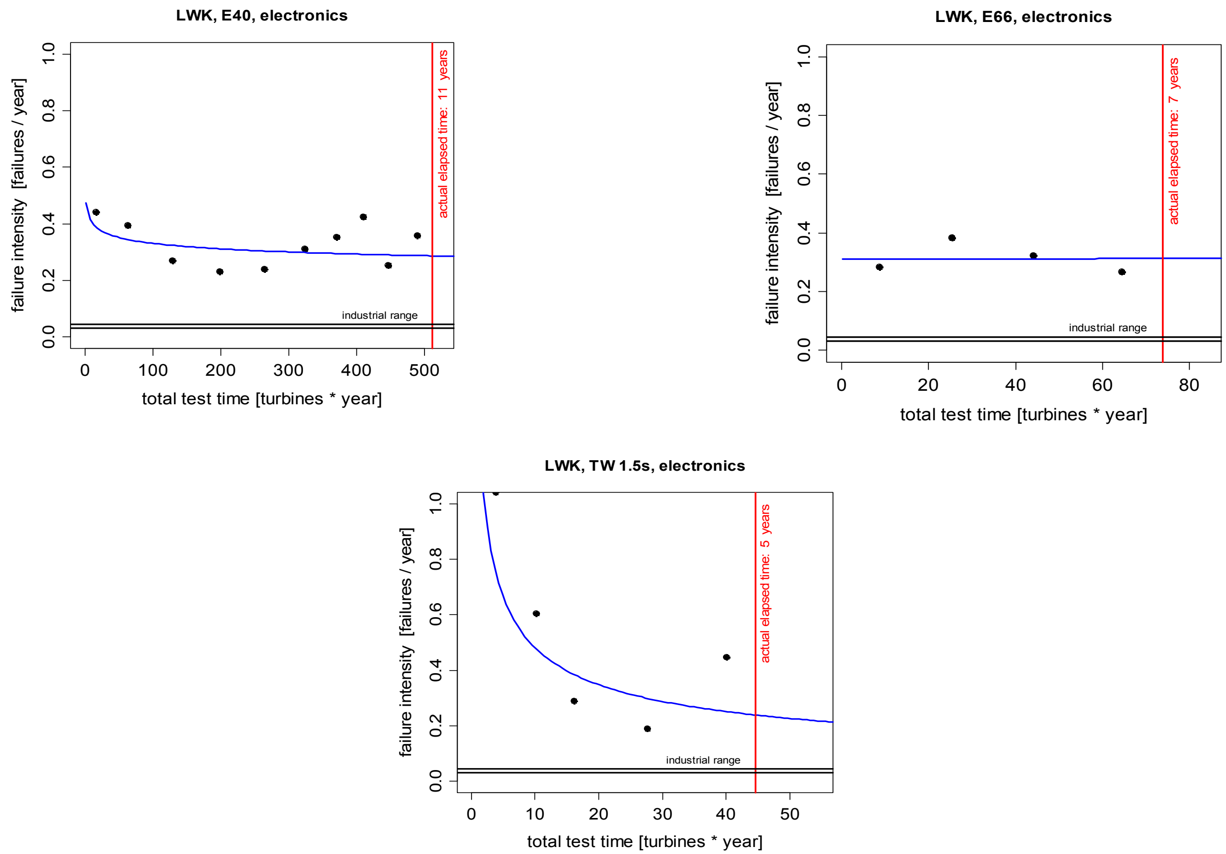

Figure 4.6: Variation between the failure rates of electronics subassemblies, or converter, using the PLP model, in the LWK population of German WTs.

The upper two are low speed direct drive generators with fully rated converters while the lower two are high speed indirect drive generators with partially rated converters.

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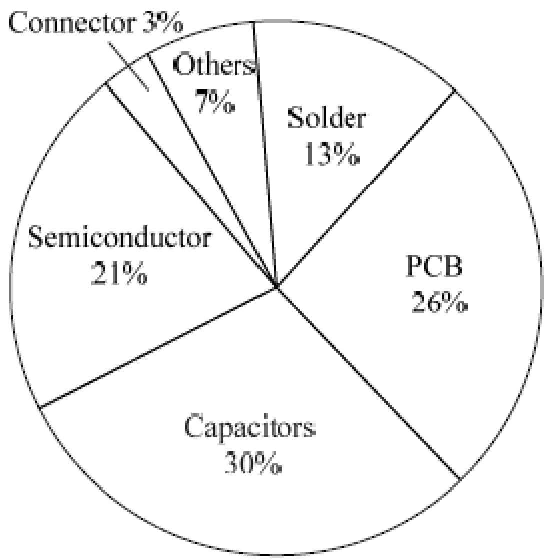
Reliability of Electronics, Important Root Causes

1.Components



Failure root cause distribution for power electronics from E Wolfgang, 2007

2. Environmental conditions

- Stochastic variation of the wind
- Diurnal variation of the weather
- Geographical location

3. Control

- Excessive I/O from converters
- Uncoordinated Alarms from excessive I/O
- False alarms causing unnecessary trips

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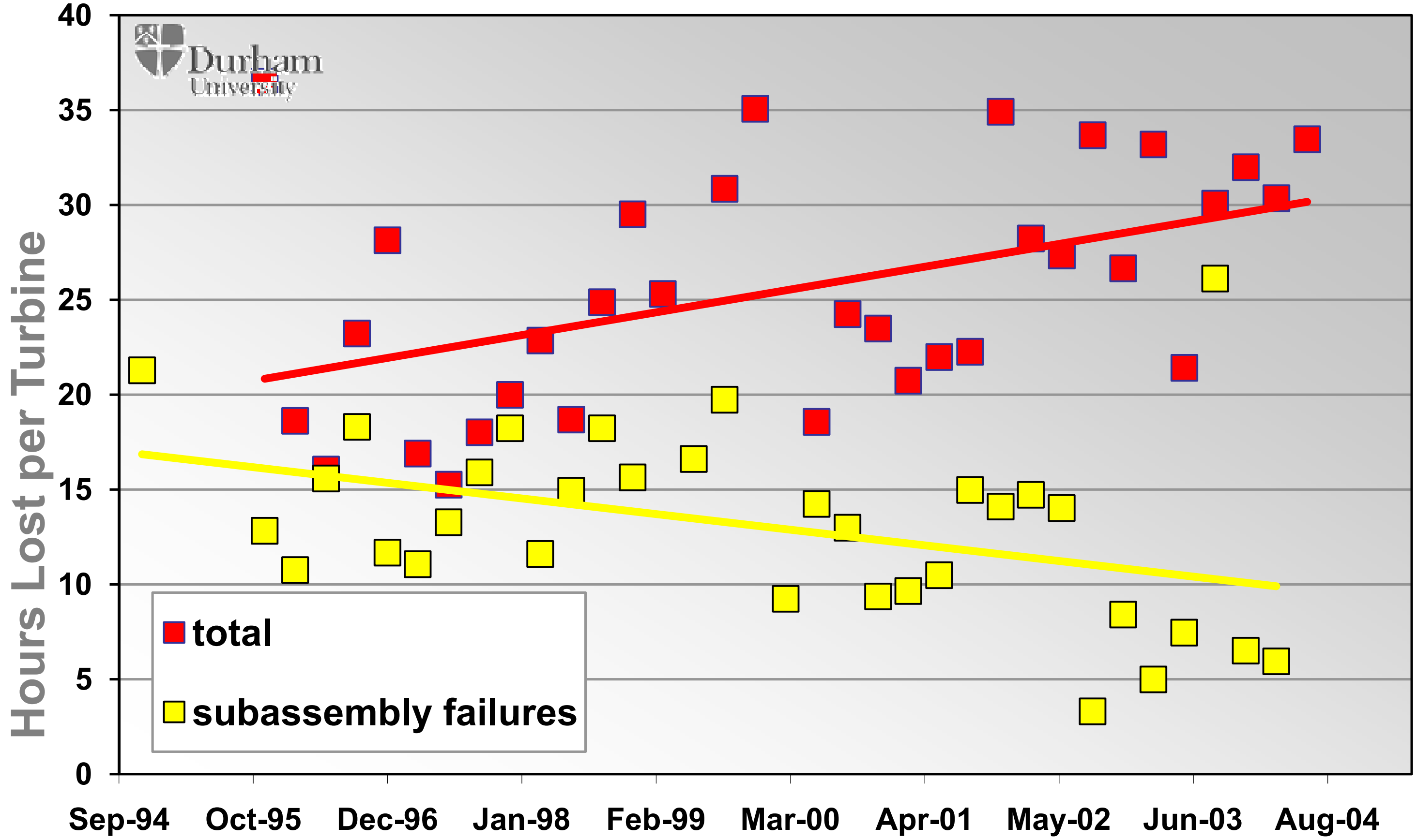
Downtime of Wind Turbines Germany 1994-2004



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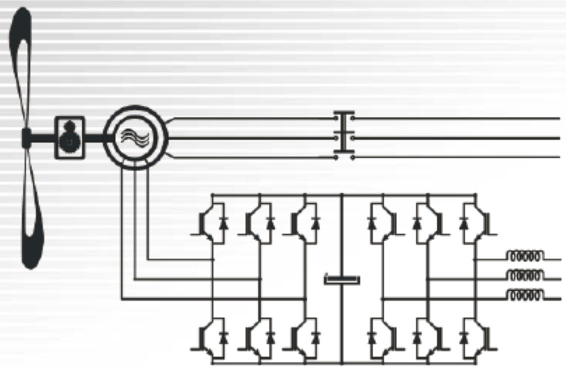
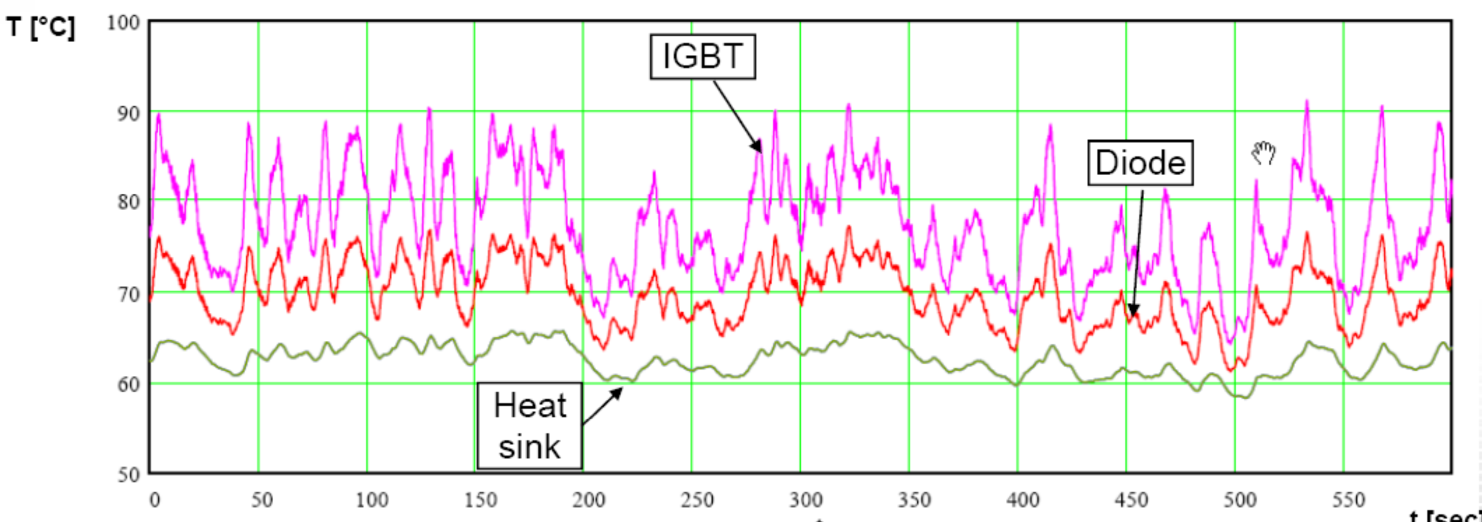
Variable Load of Wind Power Line Side Inverter

Load Conditions in Wind Turbine Inverters

SEMIKRON innovation+service



- Very high load cycles - 20 years of operation
- Low fundamental output frequency
- High load for freewheeling diode on converter section



Typ. Load Cycle of Wind Turbines Inverter

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Variable Load of Wind Power Generator Side Inverter

Load Conditions in Wind Turbine Inverters

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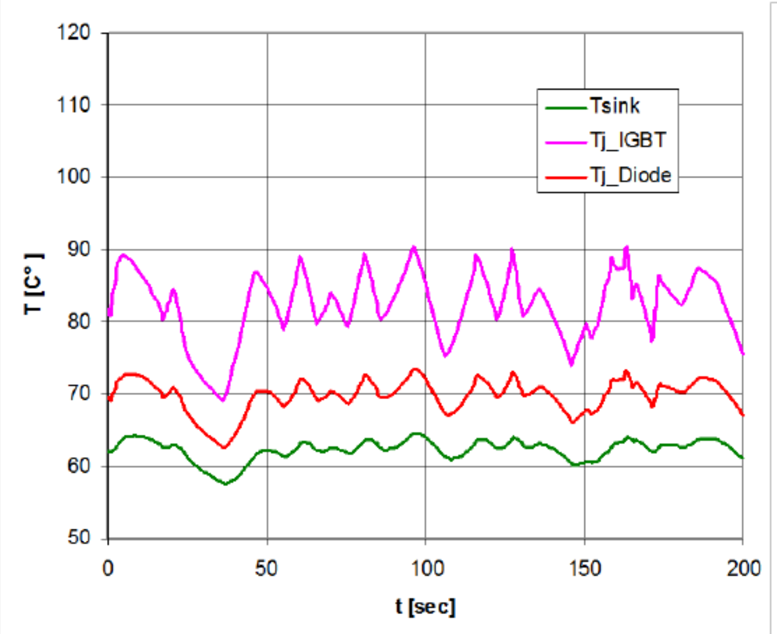
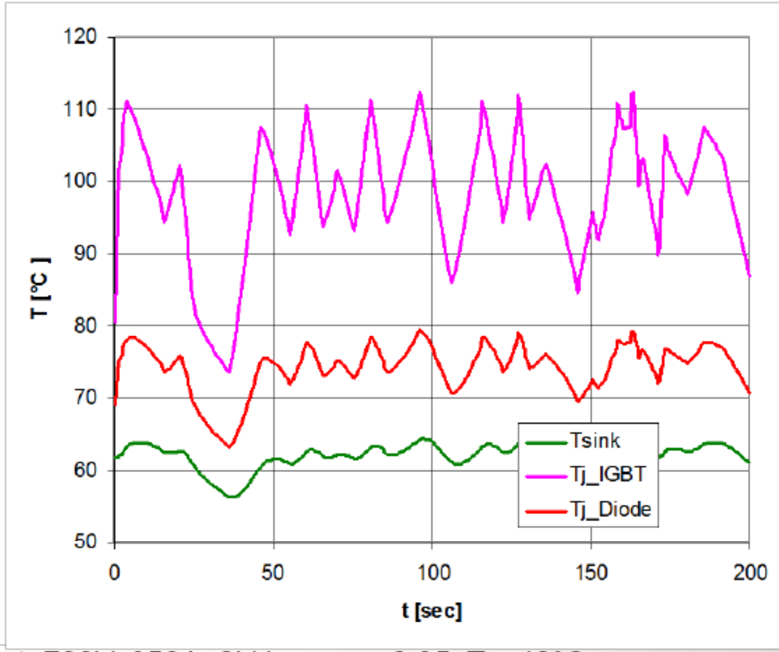
- Low Speed Operation of Rotor Converter leads to an increase of the junction temperature due to transient thermal impedance

50 Hz Operation dT = 20K



2Hz Operation dT = 40K



Condition: SKiiP 2013GB172, Vdc=1200V, Vout=700V, 650A, 2kHz, cosφ=0,95, Ta=40°C

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Conclusions

- Definitions of Availability are open to interpretation
- Unreliability > 1 failure/turbine/year is common
- Unreliability increases with turbine size
- Such unreliability will be unacceptable offshore
- Offshore we need unreliability < 0.5 failure/turbine/year
- Unreliability concentrated mainly in the Drive Train including electrics
- Some unreliable subassemblies are surprising:
  - For example gearboxes are not unreliable
  - But gearbox failures cause large downtime and costs
  - But electrical parts are unreliable
  - Cause less downtime but significant costs, their downtime will increase offshore
- For electrical parts the root causes from these surveys are not clear:
  - Components
  - Environmental conditions
  - Controls
- But the highly variable loading on turbines is clearly a factor
- And false alarms are almost certainly a factor
- Pre-testing is essential to eliminate early life failures

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Thank you

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- www.supergen-wind.org.uk/
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