Wind Turbine Reliability

Wind Turbine Reliability Workshop

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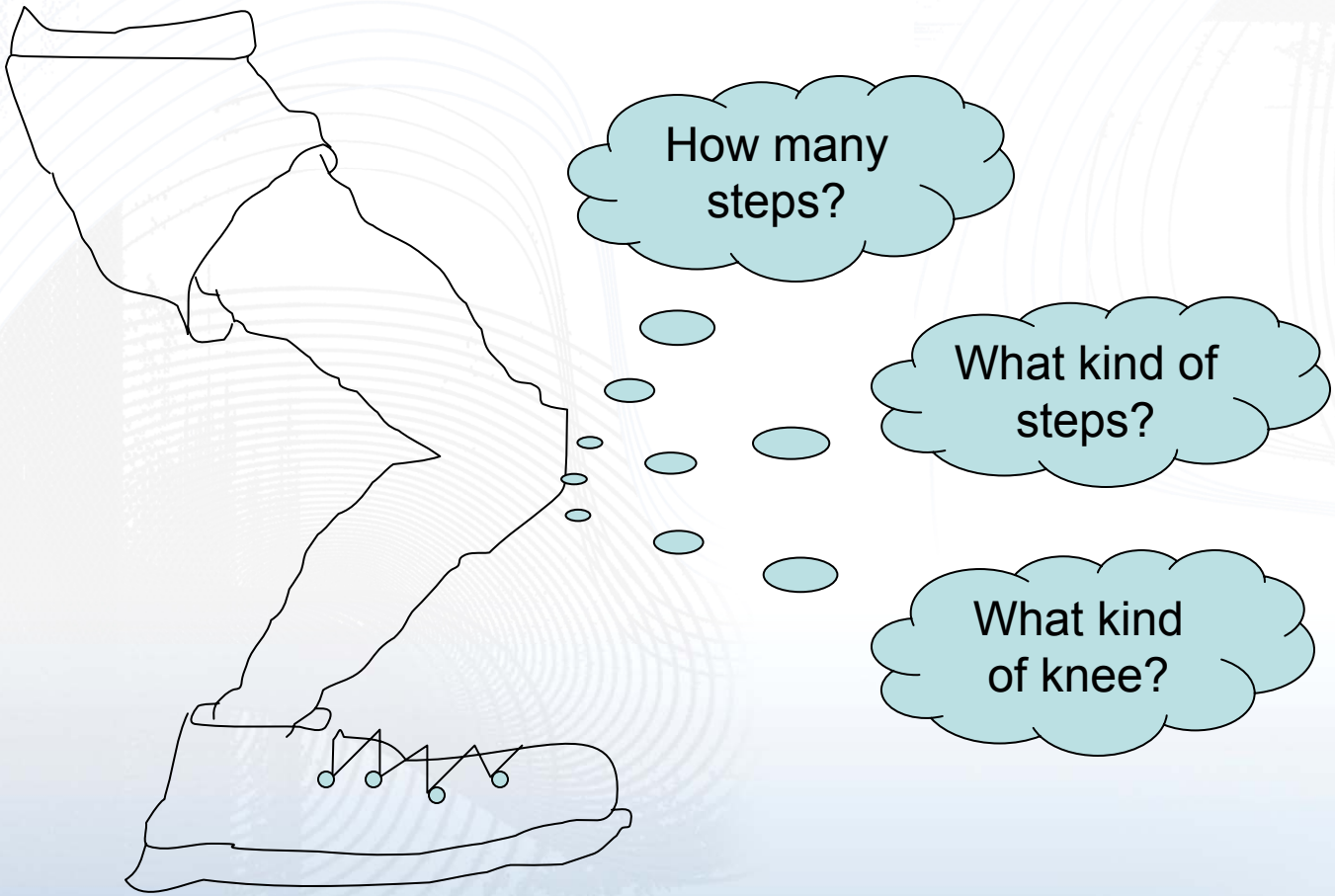
Opening Thoughts



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Turbine Health Monitoring Themes

- Wind Speed Distribution
- Load Histogram
- Fatigue Limit
- Load-Life Exponent
- Load Cycles
- Design Life
- Ultimate Loads
- Damage Equivalent Loads
- Extreme Loads
- Remaining Useful Life

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Motivating Questions

1. How long will my wind turbines last?
2. What parts will fail first?
3. Which turbines will fail first?
4. How can I make them last longer?

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All Parts Wear Out

If……

There is relative motion in contact

- Bearings, gears, seals

There are stress reversals

- Tower and main shaft bending, blade flexing

There are temperature extremes

- Generator windings, hoses, lubricant

In general, 'damage' is not proportional to load!

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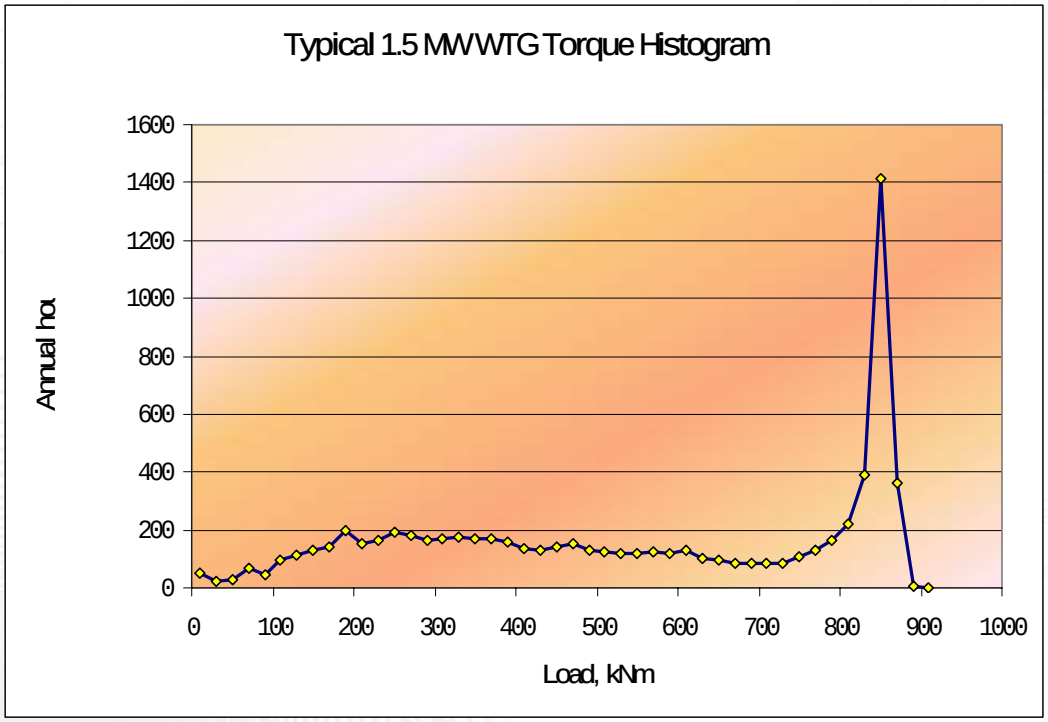
Representing Duty Cycle



In general, 'damage' is not proportional to load!
10 hrs at 1000 kNm = 100 hrs at 500 kNm
for bearings

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Expected Life

- **Turbines nominally designed for 20 years**
- **Ideal wind regime - e.g. Rayleigh distribution**
- **Standards for load events – e.g. EOG, ECD**
- **Allowable fatigue and ultimate loads**
- **Safety factors to cover uncertainties**
- **Mathematical simulation**
- **Verified with prototype turbine**

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What's Missing?

- **Proxy turbine is rarely at 'design' conditions**
- **Actual turbine is rarely at 'design' conditions**
- **Turbine components are complex**
  - Manufacturing inconsistencies
  - Material variation
- **Not all load events accounted for, e.g.**
  - yaw stiction
  - negative shear
  - structural defections
  - component wear

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Example

Whirly 1700

- 1700 kW
- IEC Class IIa
- Multiple component suppliers

Mighty Wind Site

- 7.5 m/s mean wind speed
- 18% TI
- Edge of plateau
- Icing conditions

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Estimating Remaining Useful Life at Mighty Wind

Percent of years used up

- Neglects capacity factor

Percent of design kWh accrued

- But damage is not proportional to load!

Monitor actual loads at site/turbine

- Provides ‘time at load’
- Can be estimated from ???

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Monitoring Mighty Wind Site

Loads instrumentation of all turbines

- Costly, enormous data set

Loads test on selected turbines

- May miss anomalies for some wtg's

'Key indicators' on all turbines

- Ideally using existing sensors

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Key Indicators of Turbine Performance and Loading

Operational
Rotor power, torque, speed
Yaw and pitch activity
Vibration

Component Condition
Temperatures, viscosities

External Conditions
Wind speed, direction, TI, shear
Icing conditions

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Project Approach

Develop relationships (causal/ empirical)

- Vibration = *f* (ws, TI, dir, yaw error)
- Pitch activity = *f* (Δws, power)

Estimate damage contribution rate

- Compare to design damage rate

Identify critical events and conditions

- Off-yaw, start/stop, resonance

Identify 'outlier' turbines

- Due to location, alignment, damage

Virtual turbine, SCADA data, modified GEC tools

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Challenges

Measurement resolution

- 10-min data, capturing transient events

Access to signals

- Duplexing, porting, additional sensors?

Accounting for 'true' failure rates

- Optimism and conservatism

Accounting for turbine variation

- Not all wtg's are the same

Architecture

- Interface with data systems and user

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Comments and Questions

Thank you for your attention –
we'd like to hear your suggestions!

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