THE IMPORTANCE OF TORSIONAL VIBRATIONS IN THE ENERGY TRANSITION

ETN 2020 – Frits Petit

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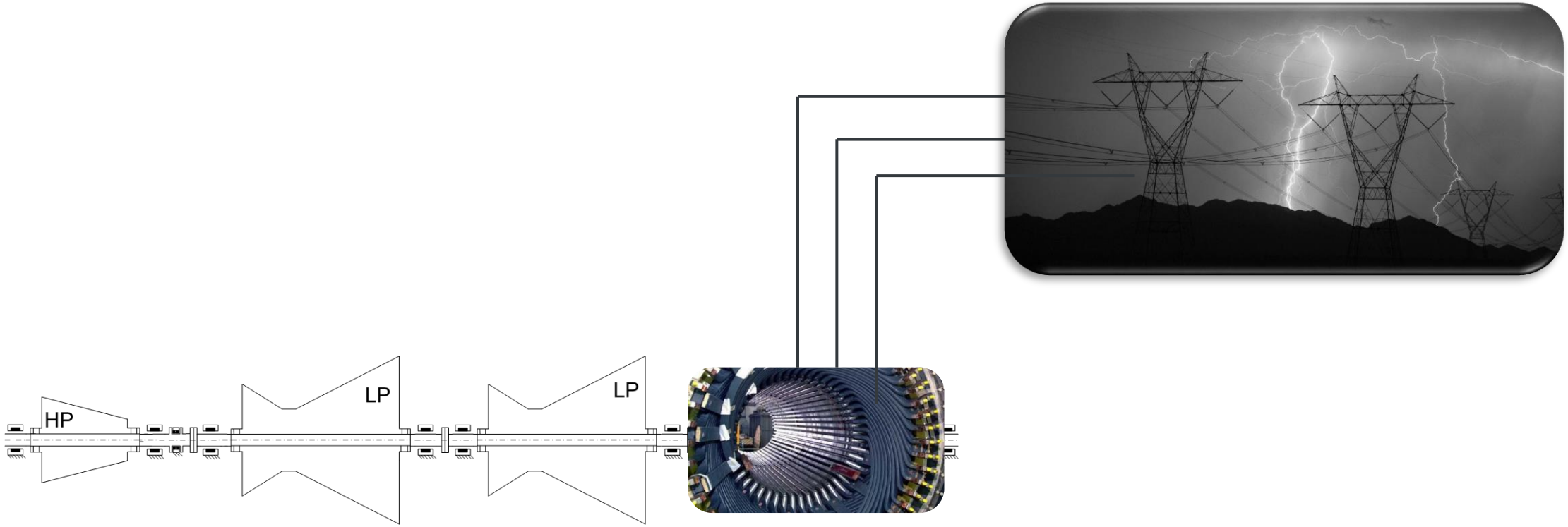
Torsional grid interaction

Electrical perturbations on the grid are transferred into torsional vibrations



The electricity grid is drastically changing

Increased risk for torsional vibration interaction

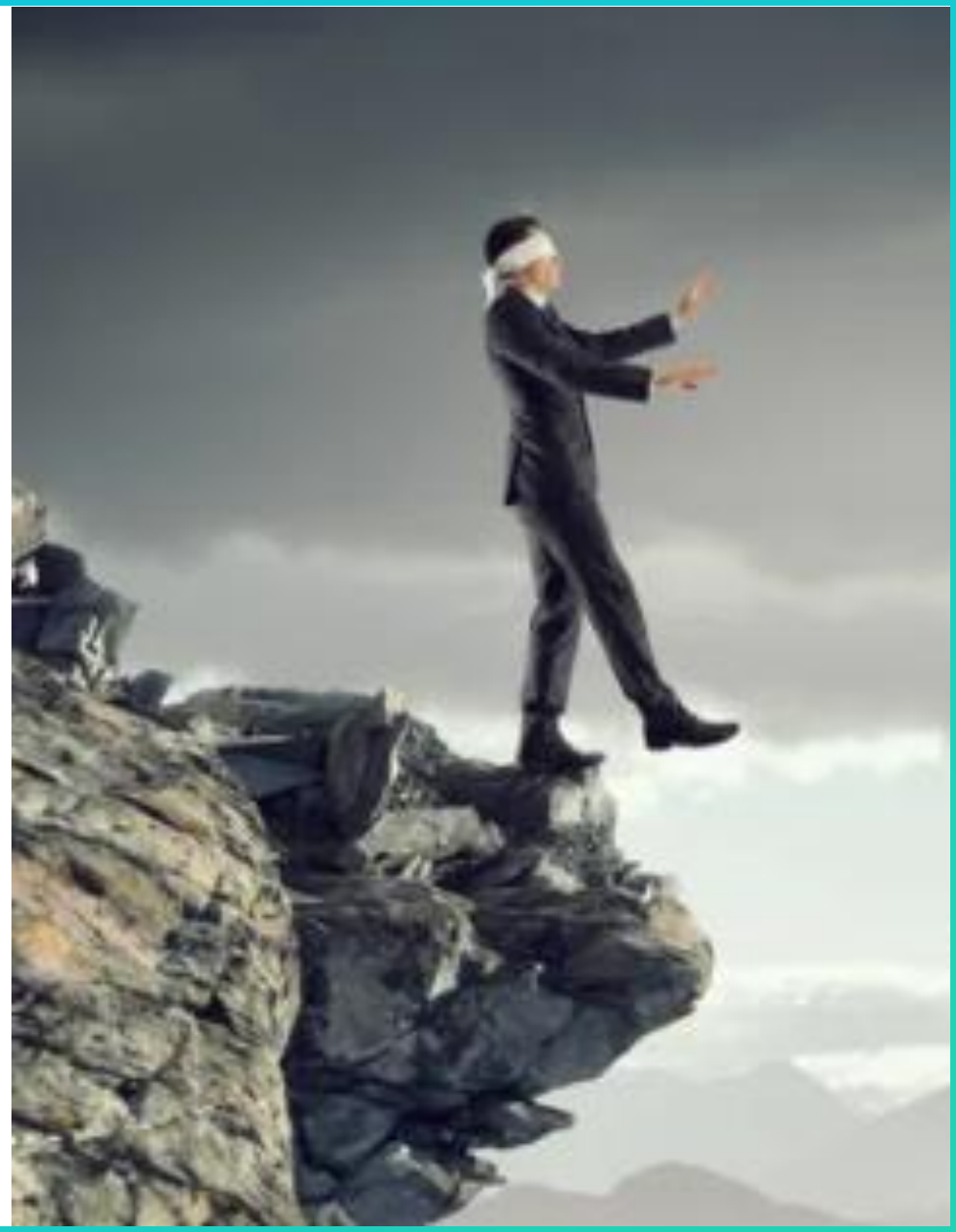
Power electronics

Conventional power plant

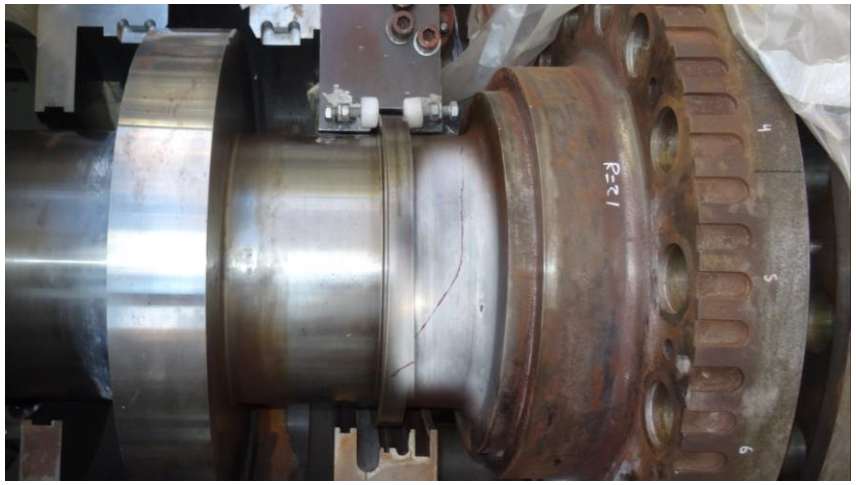
Transmission line

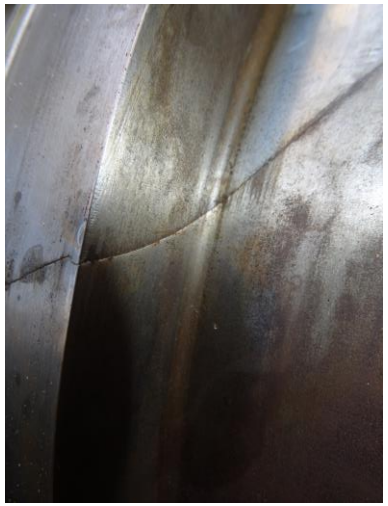
Renewables

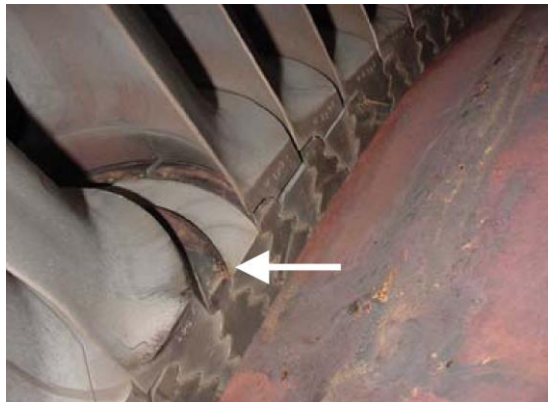
Power plants are blind to torsional vibrations

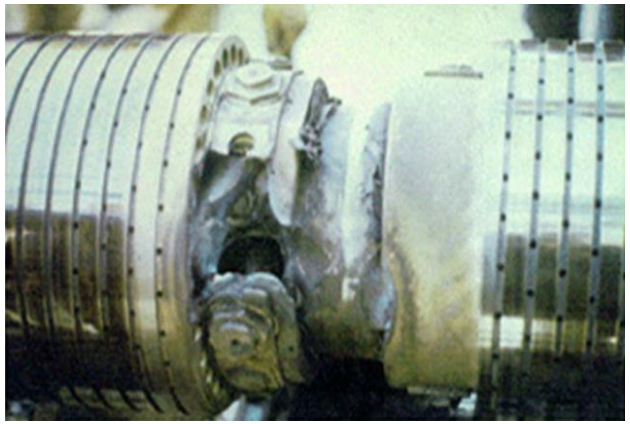


Torsional vibrations can lead to catastrophic failures of the shaft line









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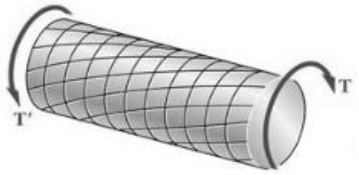
Key aspects of torsional vibrations

There are important contrasts between radial and torsional vibrations

Radial vibrations

- Vibration is felt on casing
- Internal excitation (unbalance)
- Usually sufficiently damped
- Advanced criteria/standards
- Closely monitored

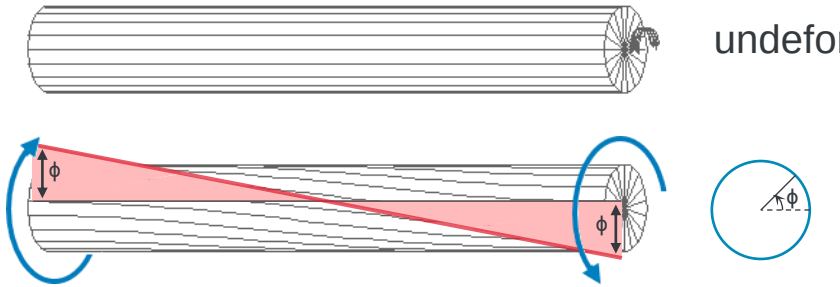
Torsional vibrations



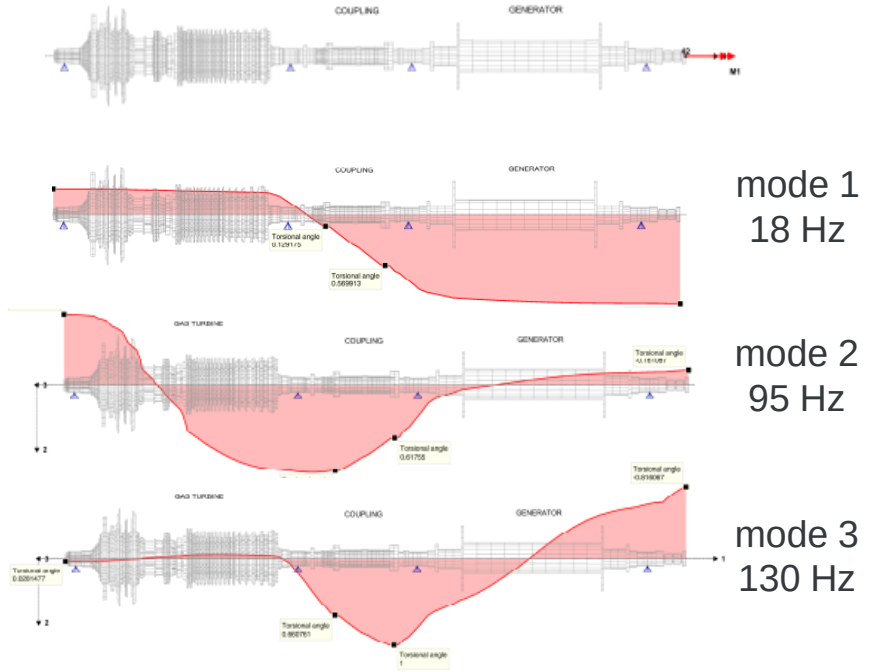
- ‘Hidden’ vibration
- External excitation (grid)
- Very lightly damped
- No clear criteria/standards
- Typically not monitored

Torsional vibration is a twisting motion of the shaft line

Basic cylinder



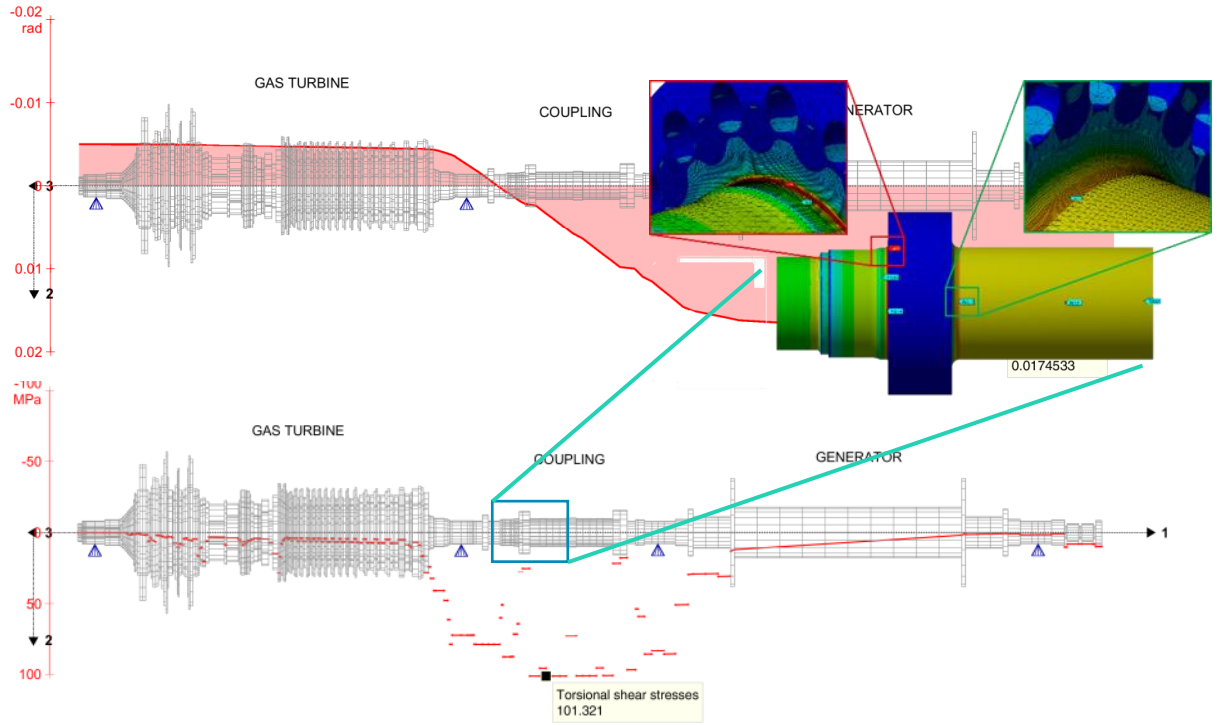
Turbo-generator shaft line



Highest torsional stress for sub-synchronous modes typically in intermediate shafts

mode 1

18 Hz



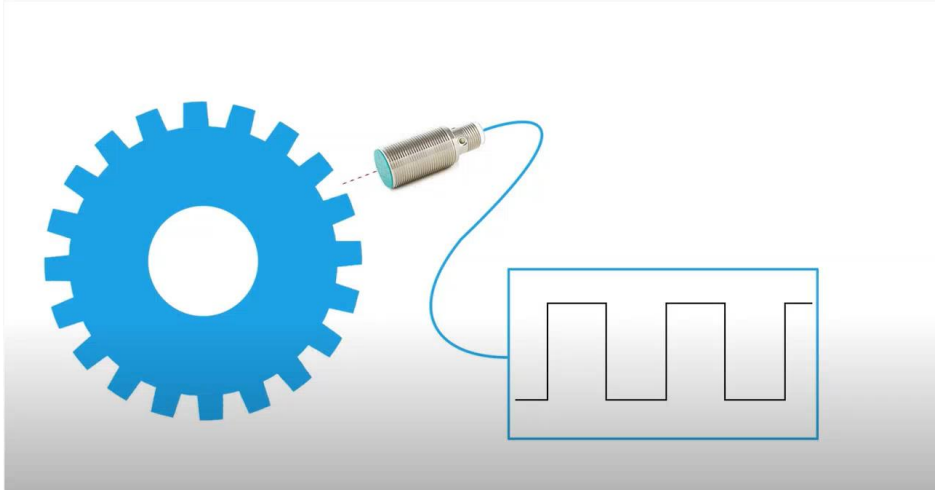
How to measure them ?

In most cases existing speed sensors are sufficient

- Magnetic pick-up facing toothed wheel
  - Overspeed protection
  - Speed control
- Galvanic isolation
  - Avoid disturbance of measurement chain

In most cases existing speed sensors are sufficient

- Determine torsional vibration amplitude
  - Time in between zero crossings or pulses (MHz clock)



Many different pulse position based sensors exist

Magnetic pick-up

Most common + very robust

Existing speed sensors

Optical

Zebra-tape

Temporary campaign

Encoder

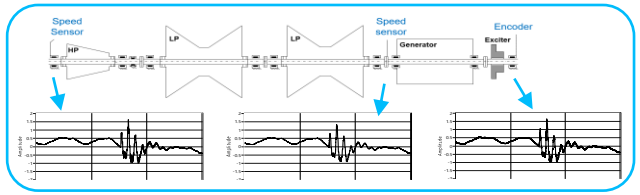
Shaft end

Very precise

Measurements based on stress/strain are also possible

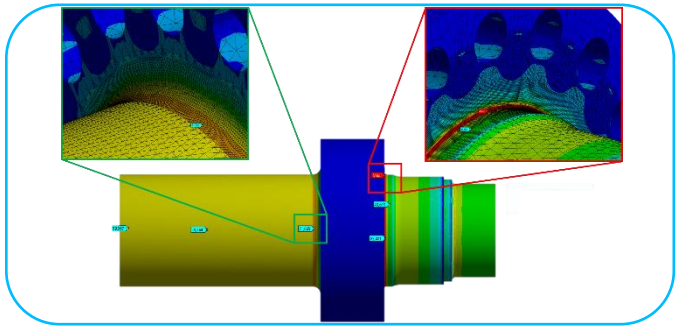
- Inverse magneto-strictive sensor
  - Stress changes magnetic induction for a given magnetic field
  - Contactless (+)
  - Sensitive to air-gap (-)
- Strain gauges
  - Direct measurement of strain (+)
  - Not straightforward to implement (-)
  - Less robust (-)

Fatigue lifetime calculation scheme

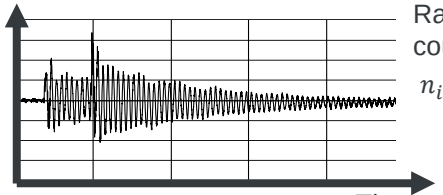


Torsional vibration measurements

Torsional vibration model



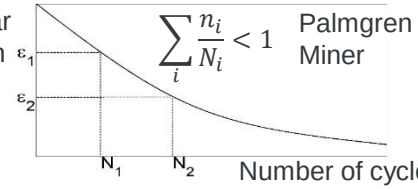
Shear strain at critical location



Rainflow counting

n_i, ε_i

Shear strain



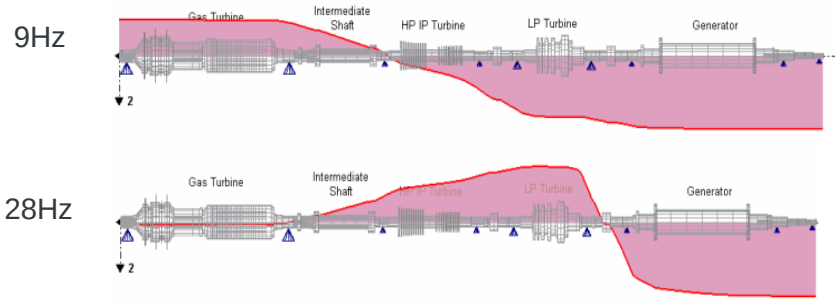
$\sum_i \frac{n_i}{N_i} < 1$

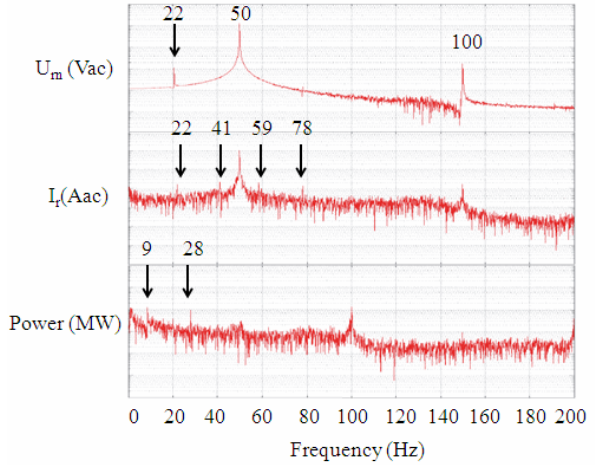
Palmgren Miner

Number of cycles to crack initiation

What about electrical measurements ?

- Existing fault recorder ?
  - Trigger not possible on sub-synchronous components
  - Additional measurement device required
- Sub-synchronous components can be detected, but…
  - Translation electrical to mechanical not straightforward
  - Severity more difficult to assess (indirect measurement)

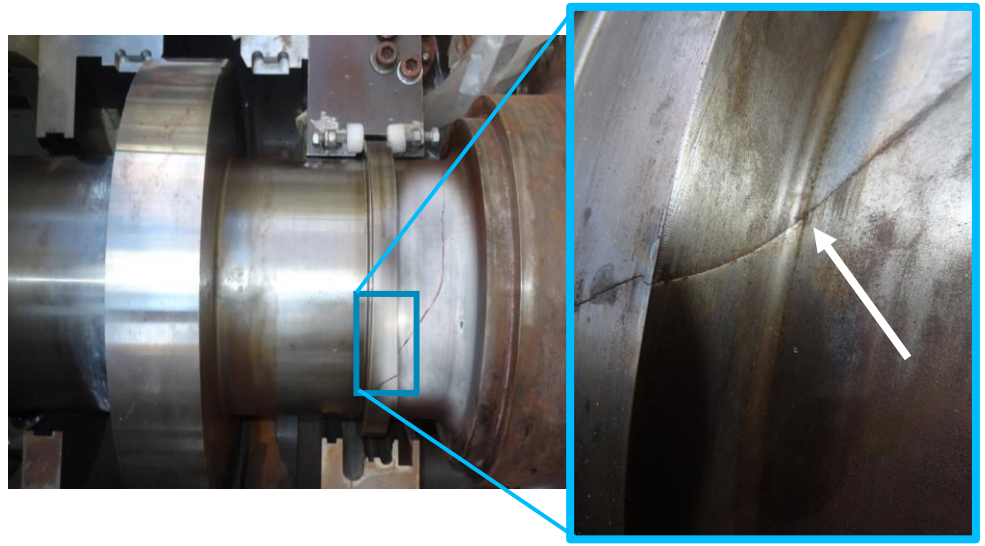


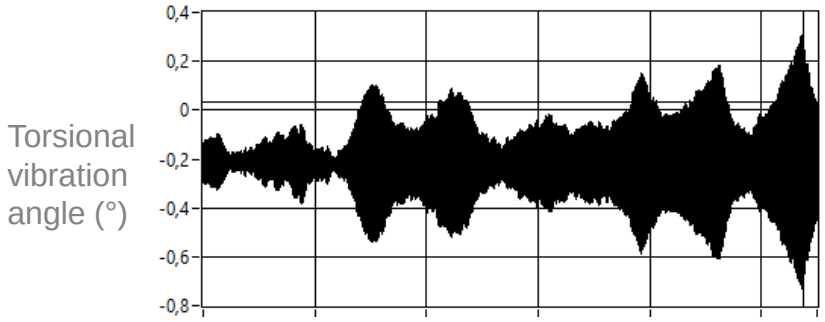


A recent incident

Compressor rotor crack due to torsional vibrations

- Crack revealed in 2019 after trip due to high lateral vibrations
  - Position + orientation points to torsional vibrations
  - Confirmed by finite element model
- Excessive torsional vibrations were revealed
  - Only in specific conditions
  - Present since 2010, yet never identified
- Mitigation measures
  - Modification of PSS (at the source of the issue)
  - All units equipped with protection system





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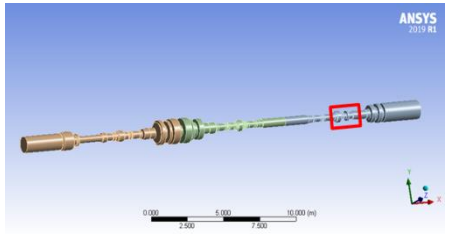

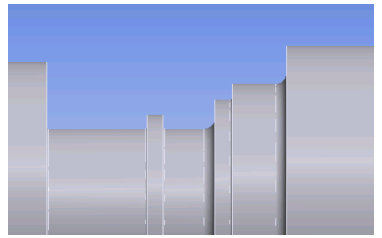

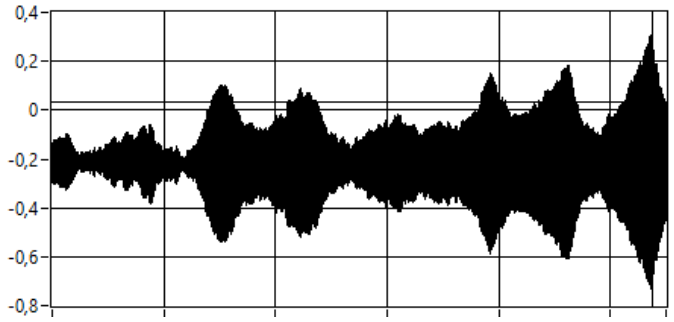

Conclusions

- Energy transition increases risk for torsional vibration issues
  - Modified grid configuration
  - Less stable grid
  - More power electronics
- Monitoring torsional vibrations seems indispensable
  - Power plants are typically blind
  - In most cases, existing sensors can be used

Thank you for your attention

We welcome your questions

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