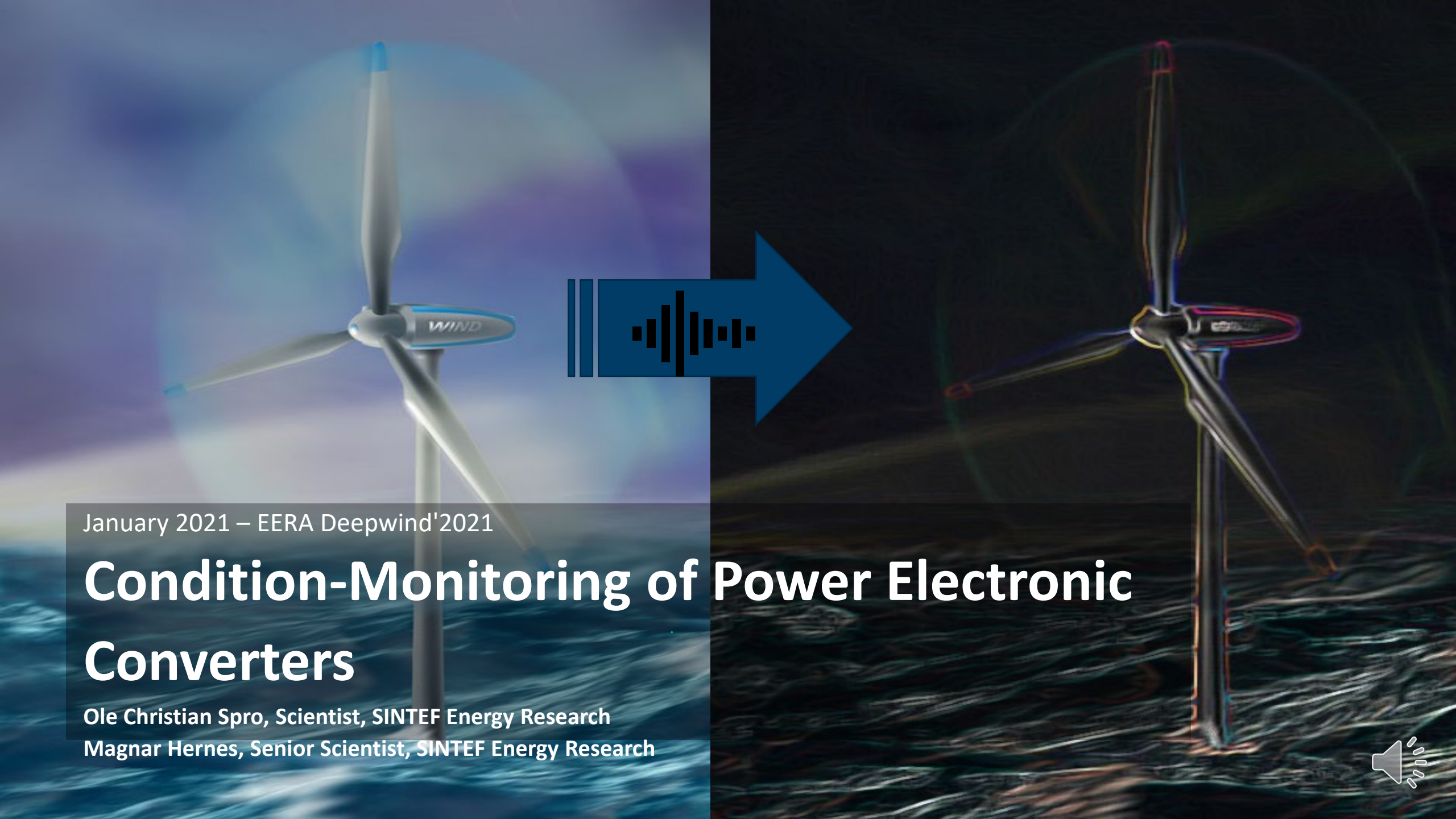

January 2021 – EERA Deepwind'2021

Condition-Monitoring of Power Electronic Converters

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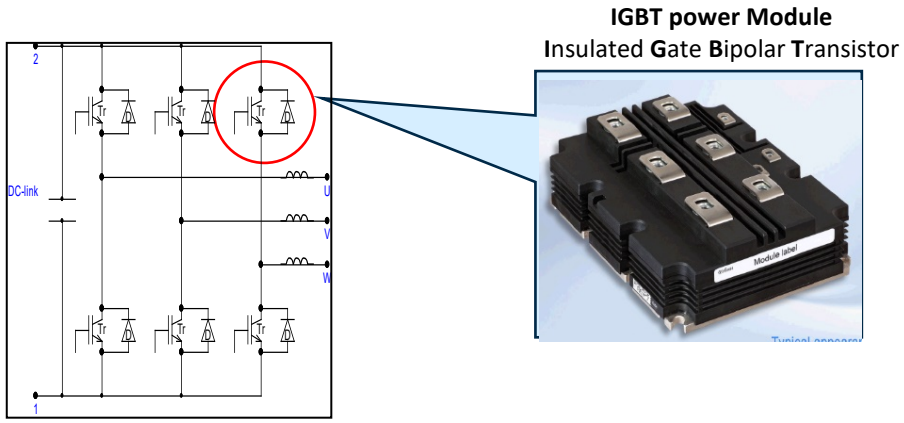
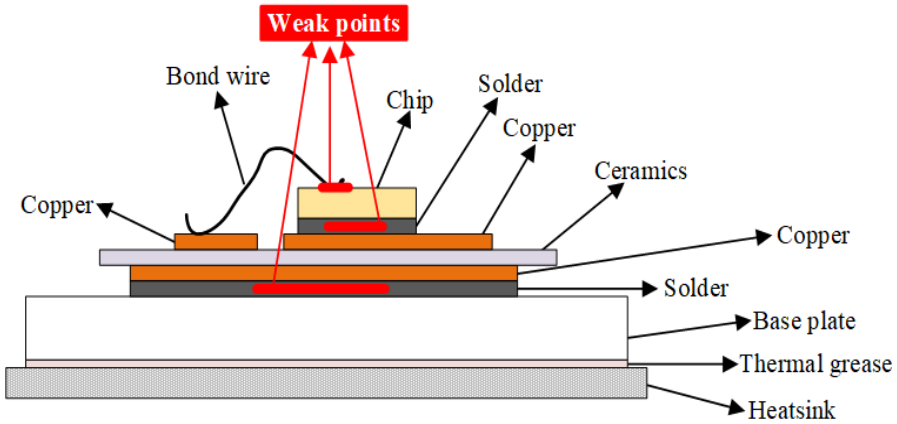
Converter failures modes in short

- DC-link capacitor or dc-bus insulation failures
- Gate driver failures
- Failure of often tied to power module
  - Spontaneous failures due to overload events – E.g., over-voltage, short-circuit.
  - Failure due to environmental hazards – E.g., humidity, cosmic radiation
  - **Failure due to degradation and aging**
    - Thermo mechanical stress between layers
    - ➢ *Degradation until End-of-Life (**EoL**)*
      - Lifetime models describe expected average lifetime when exposed to this stress.





Options for monitoring

Option 1

Counting thermal cycles

- Estimation of remaining lifetime based on existing measurement hardware in the converter system + lifetime models
- Least invasive for existing equipment

Option 2

Direct measurement of aging parameters

- Better estimation of health condition, warning typically close to the failure moment.
- Requires specific hardware (V_{CE}, R_{Th}, $I_{g,leak}$)

Option 3

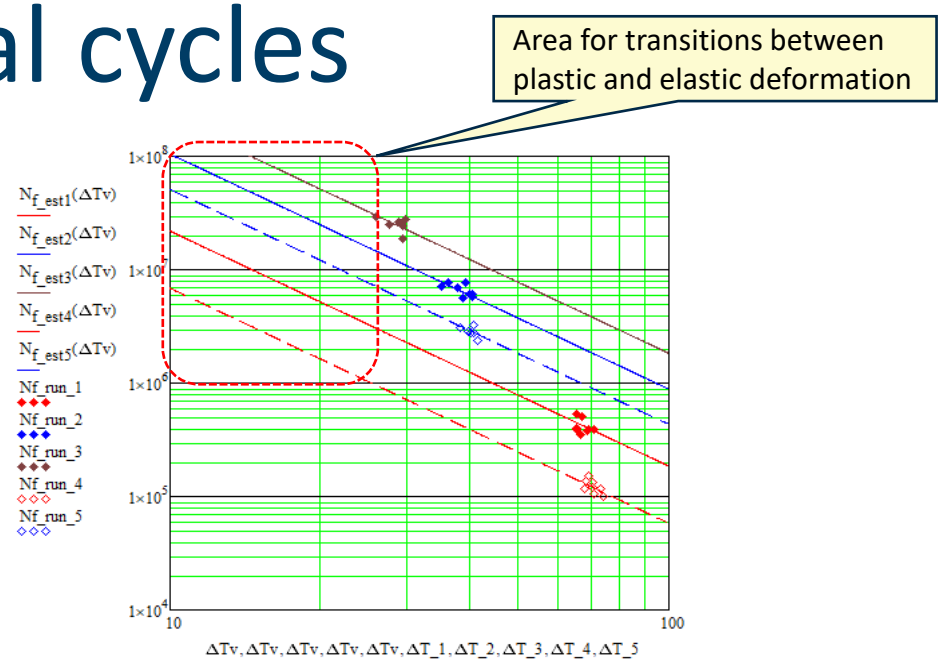
Data-driven models

- Training advanced algorithms on data set containing experienced failures or normal condition
- Statistical methods

Option 1:
Estimation by counting thermal cycles

ReliPE[1] research project – verifying known lifetime model for IGBT power modules.

- Tested 100x commercial modules : Updated lifetime model parameters in Bayerer/CIPS'08 model
  - Identical IHV modules 1000A/3300V
  - Bond-wire failure mode most prominent.
  - Plastic deformation also at 30K temperature swing
- Two tests with a mix of high and low ΔT cycles – conclusion: the accuracy of accumulating partial damages is in the same range as was estimated for the test objects that were subject to fixed cycles for the compete test runs.



$$N_f = k_b \cdot (\Delta T)^{\beta_1} \cdot e^{\frac{\beta_2}{T_{j,min}+273}} \cdot t_{on}^{\beta_3} \cdot I^{\beta_4} \cdot V^{\beta_5} \cdot D^{\beta_6}$$

[1] *Reliabililty and ruggedness of high power, high voltage power electronics* – https://www.sintef.no/projectweb/relipe/

Established cycle counting method

In *ReliPE*, an online method for counting stress cycles of IGBT modules was implemented and demonstrated.

- Demonstrator in the National Smart Grid Lab, where an MMC converter was configured as "Flicker Compensator" with emulated hot spot temperature dynamics.
- Only requires measurements that are commonly available in converter systems i.e. current, voltage, control signal and temperatures.
- In addition, a thermal model of the IGBT module converter is required.