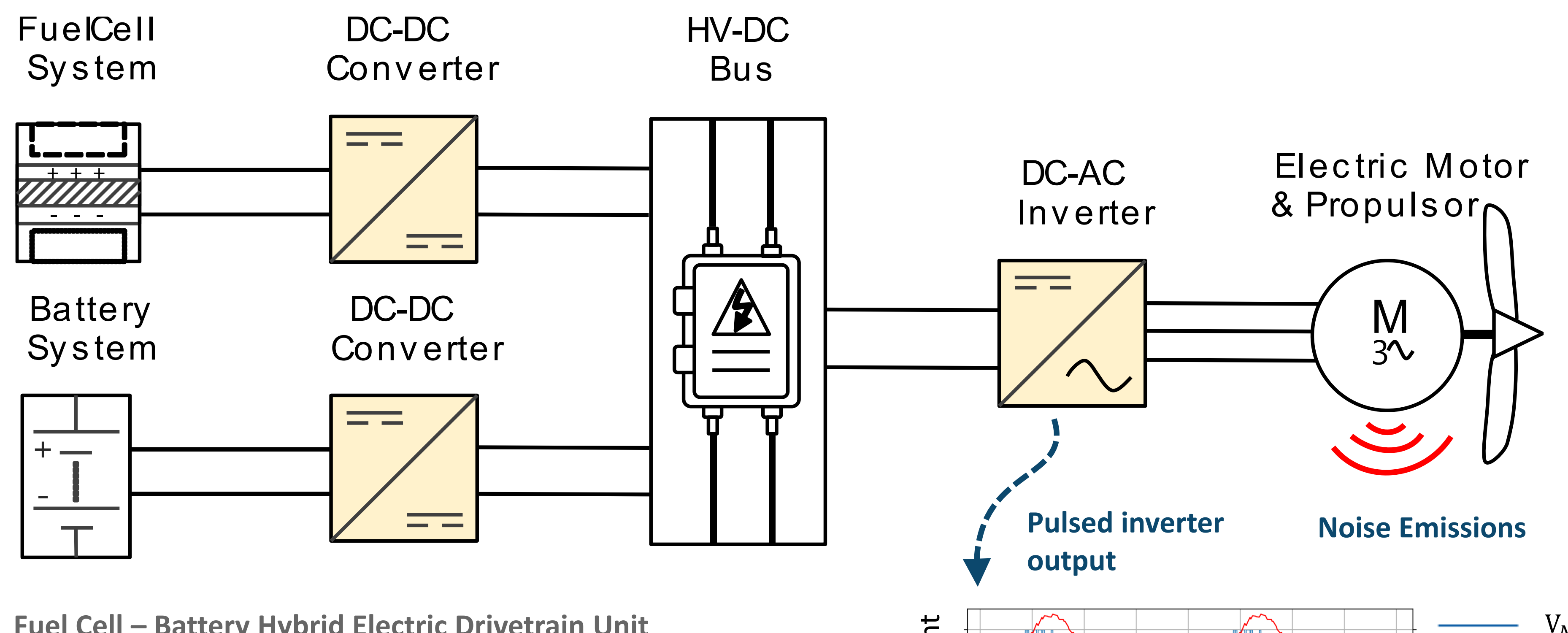


ELECTRIC POWERTRAIN POWER ELECTRONICS & ACOUSTICS

Institute of Electrified Aero Engines – German Aerospace Center (DLR)

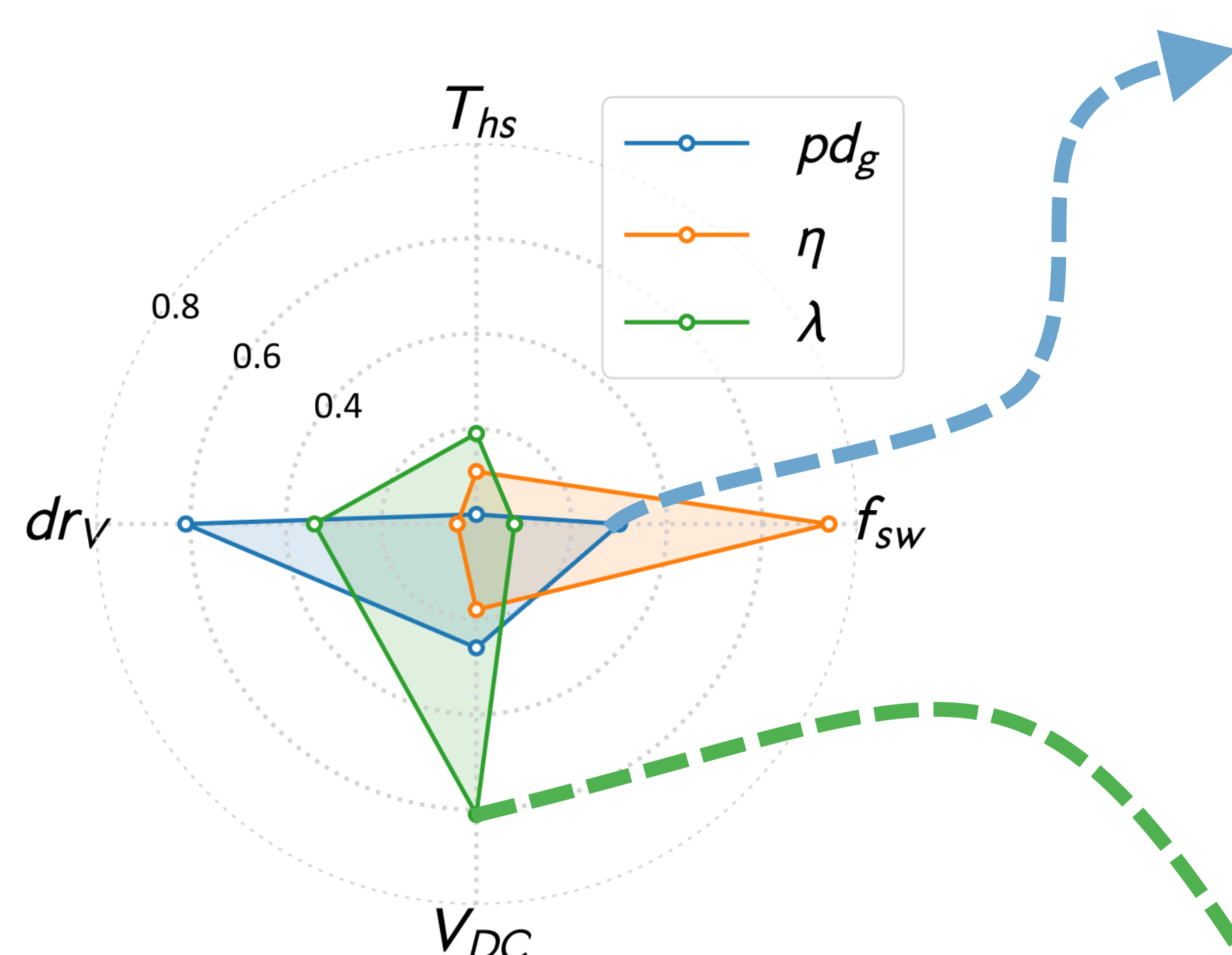
J. Kugener, E. Schneeagen



Fuel Cell – Battery Hybrid Electric Drivetrain Unit

Power Converter Design for Aircraft Concept Studies

The integration of power converters in aero engines requires a modelling approach for key characteristics such as power density, efficiency and reliability to accurately represent the power electronics domain in aircraft concept studies.



Pearson correlation factors for key input parameters and converter evaluation criteria

Results

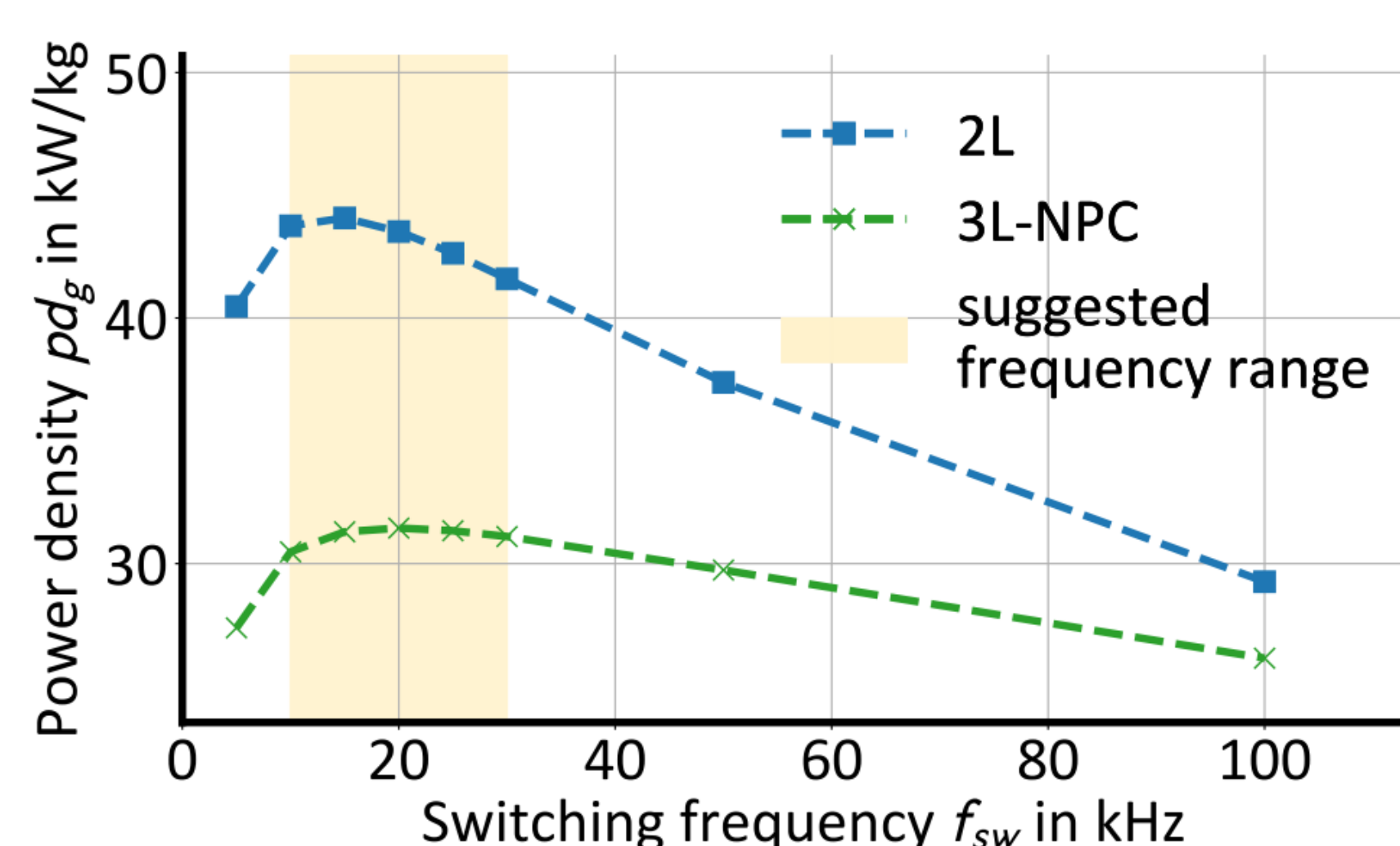
- **Total mass and volume** is dominated by passive components and the heatsink
- Voltage derating & switching frequency is a significant factor affecting **gravimetric power density**
- **System efficiency** is strongly related to the applied switching frequency
- The DC-link voltage level has a significant impact on the **failure rates**

[1] J. Kugener and S. Kazula, "Preliminary Design and Evaluation of Inverter Power Density and Reliability in Electric Aircraft Propulsion Systems," PCIM Europe 2024

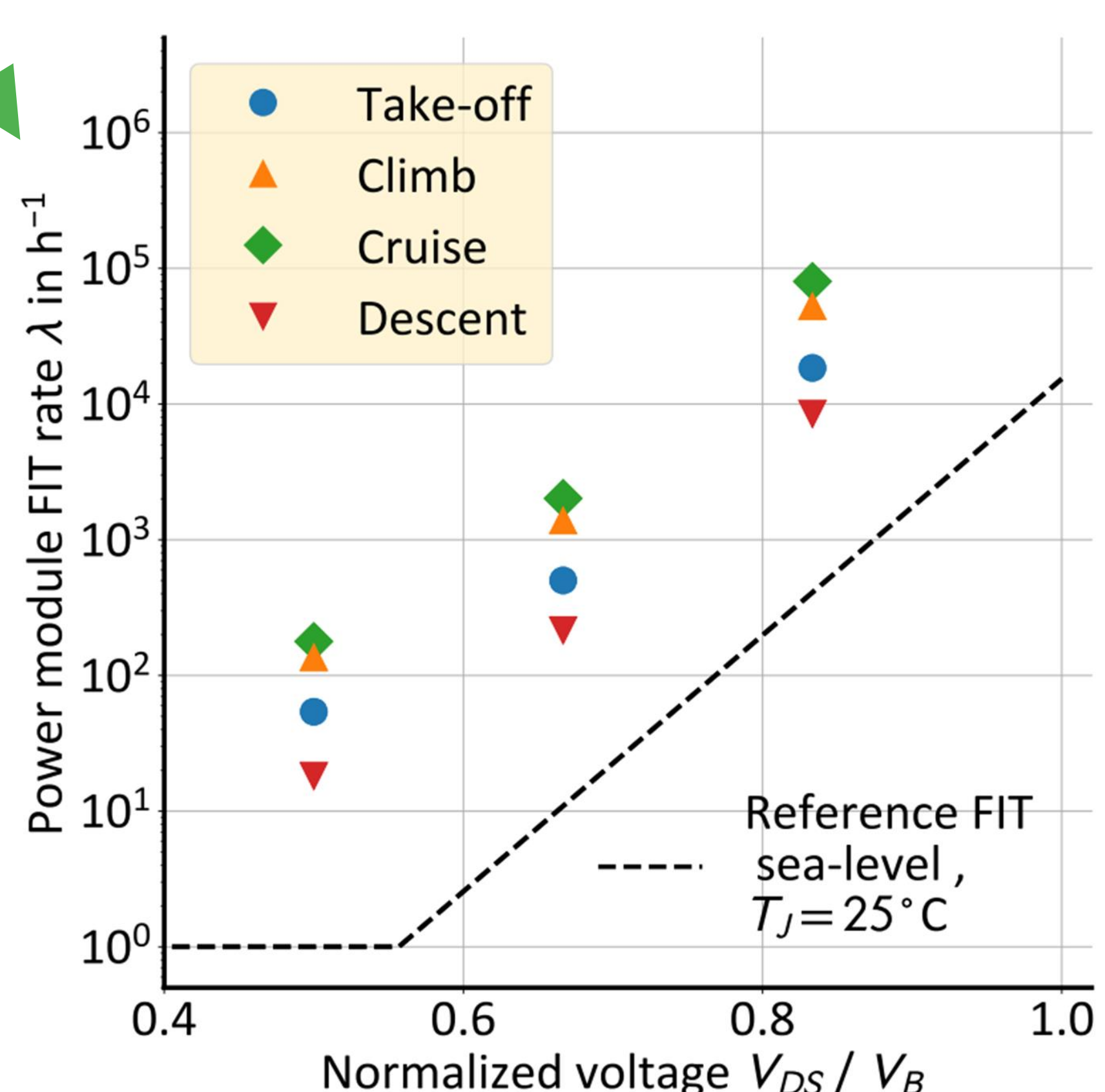
[2] J. Kugener and S. Kazula, "Reliability Assessment of Power Modules Across Mission Phases in Electric Aircraft Propulsion," ESARS-ITEC 2024

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V_{DC} : Input Voltage pd_g : Power Density
 f_{sw} : Switching Frequency η : Efficiency
 T_{hs} : Heatsink Temperature λ : Failures in time
 dr_v : Voltage Derating



Gravimetric power density over switching Frequency [1]



Mission-phase specific failure rates λ based on reference data [2]

[3] T. F. Chan, L. L. Lai, and Shuming Xie, "Field Computation for an Axial Flux Permanent-Magnet Synchronous Generator", IEEE Trans. On Energy Conversion, vol. 24, no. 1, March 2009

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Electric Drivetrain Components Objectives

Performance

Investigate power density and efficiency using component sizing and electrothermal simulations

Airworthiness & Reliability

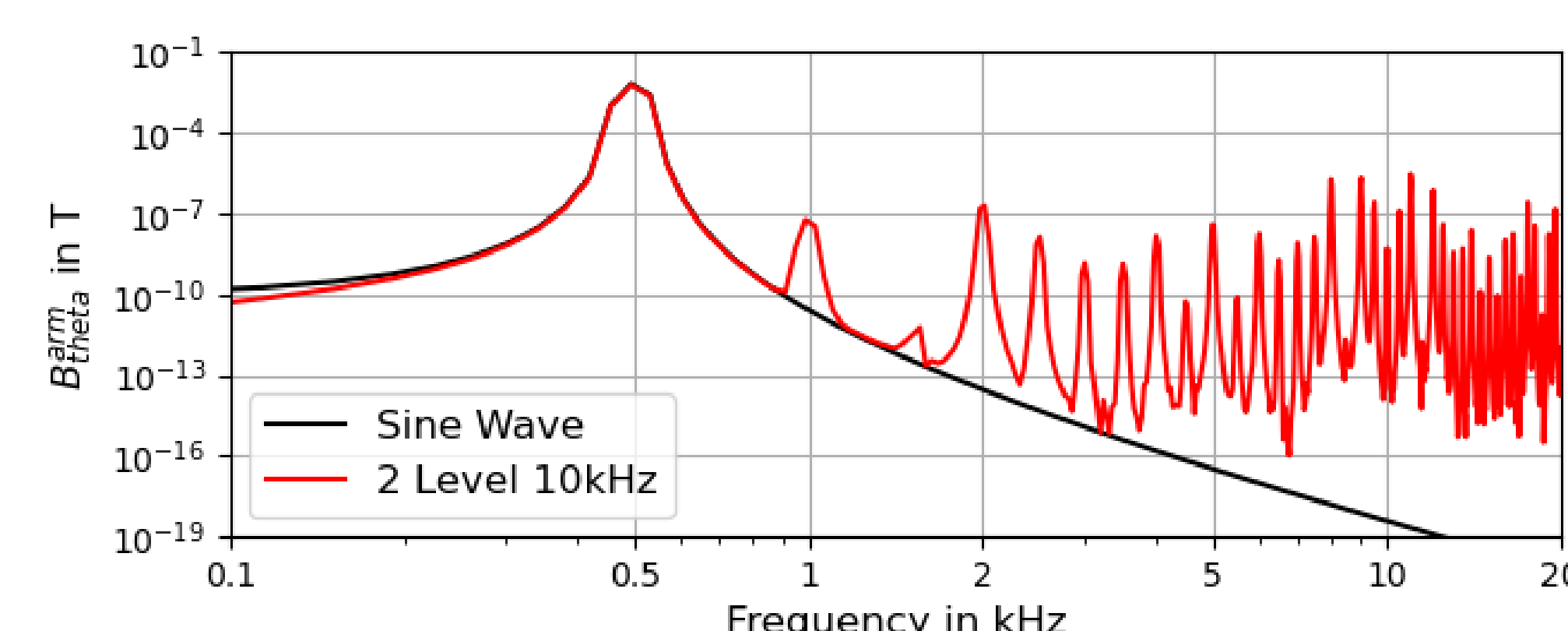
Ensure compliance with aviation standards and estimate mean time between failures (MTBF)

Environmental Impact

Focus on reducing emissions, noise and overall energy consumption

Acoustic Signature of Inverter-Fed Electric Machines

- Analytical model [3] to calculate the magnetic flux density of the armature winding for 500 Hz excitation for a sine wave and pulsed inverter output signal
- Inverter-signals with low total harmonic distortion are needed to avoid additional spectral components in the electro magnetic forces which cause noise



Conclusions & Outlook

Holistic Component Modeling

Integrated electrical, thermal and mechanical modeling of drivetrain components

Exploring Correlations

Comprehensive evaluation of power density, efficiency and failure rates for preliminary aircraft studies

Enhanced System-Level Analysis

Assessment of component synergies and system level impact