UpNext

Electric aircraft diagnostics needs

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Outline

1. Presentation of ASCEND project
   a. Context
   b. Architecture
   c. Current status
2. Diagnostics for electric aircraft needs
   a. Main challenges
   b. Possible solutions identified so far

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Airbus UpNext:

PURPOSE
Boost Airbus by accelerating future technologies

VISION
Fly the future of aerospace, Incubate talent, Inspire Airbus transformation

AMBITION 2025

Be THE reference for Technology Value Assessment

Be recognized as an inspiring place to work

Act as entrepreneurs

VALUES Keep it Simple, Be Audacious, Exploring Together

Mindset

DNA Speed Of Execution, Caring for Each Other, Open to the World

Unique value proposition

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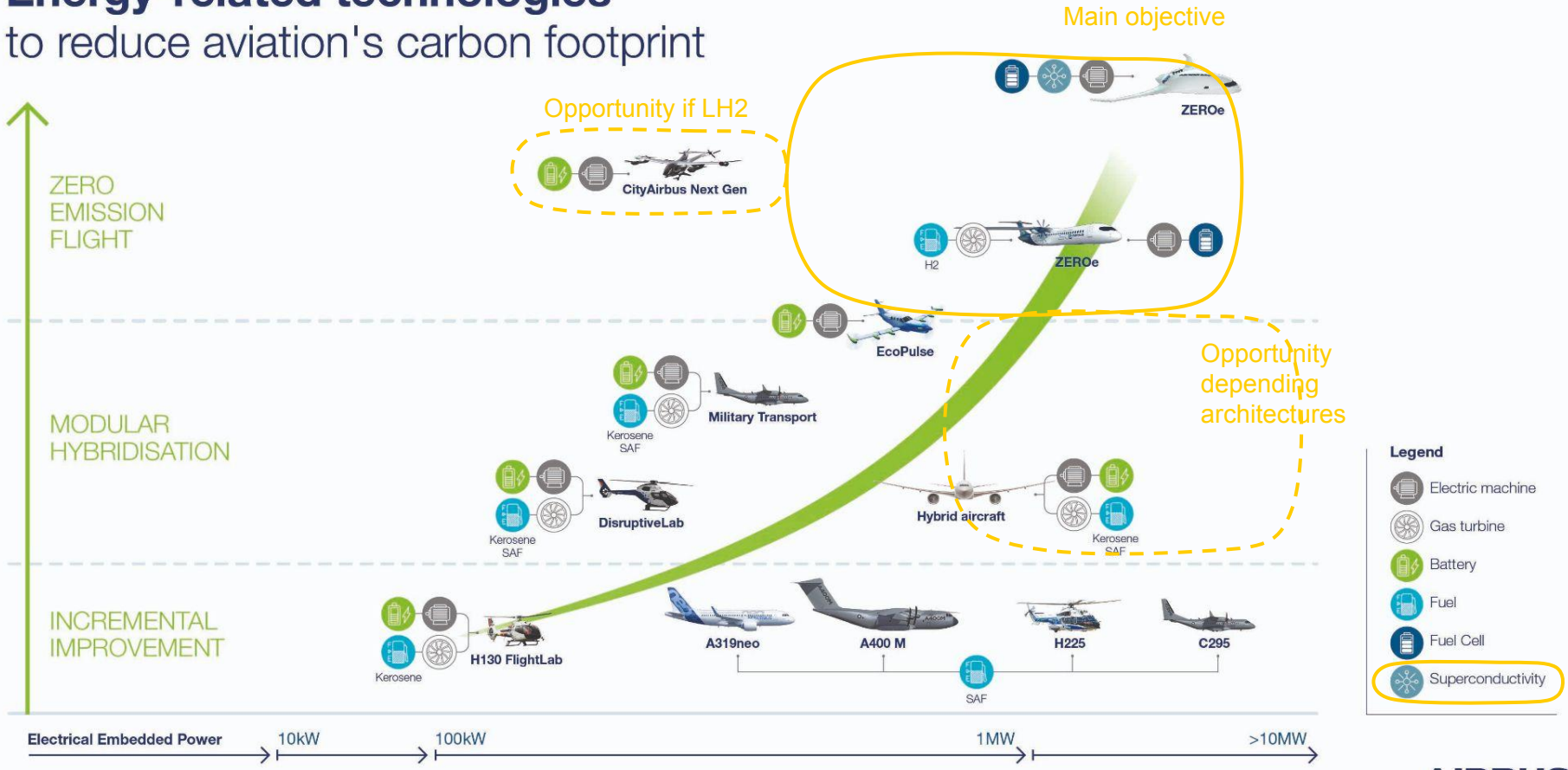
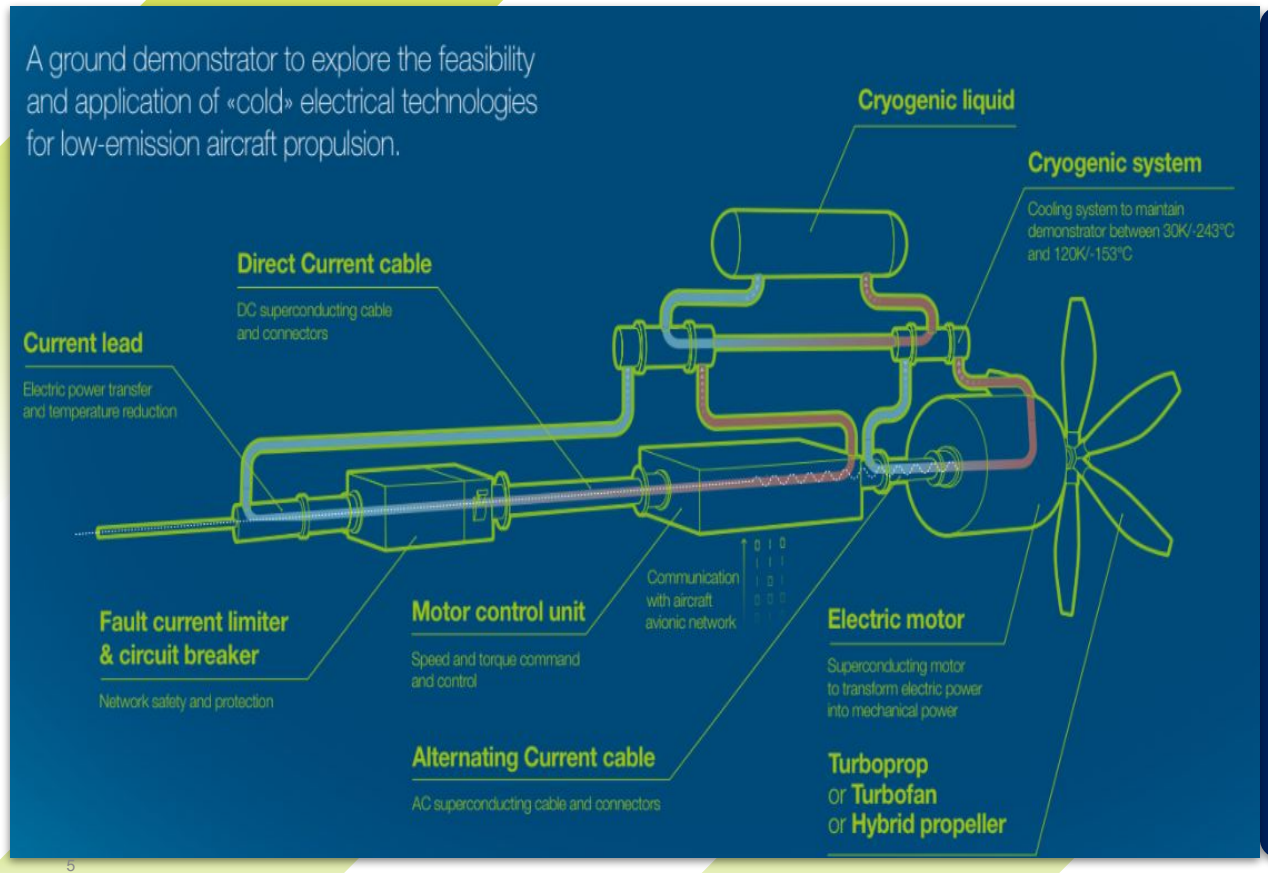
Energy-related technologies
to reduce aviation's carbon footprint



ASCEND: Advanced Superconducting & Cryogenic Experimental powertraiN demonstrator: 300V / 500kW



An Electric propulsion System

→reduce voltage below 500V
→increase efficiency by 4 to 5%
→increase power density
→enable new architecture

in **3 years**

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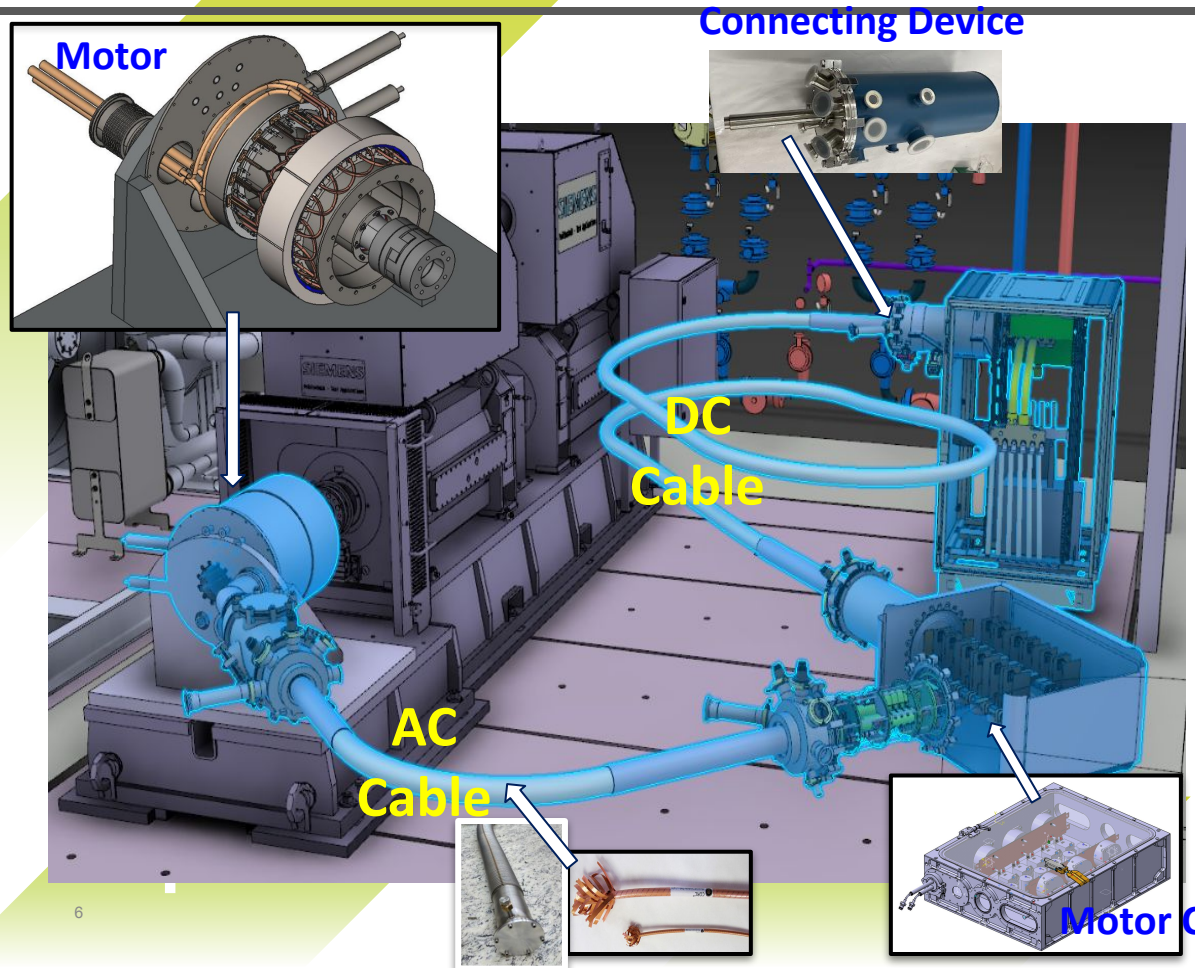
ASCEND development so far



Manufacturing / integration and testing in progress

- No showstopper
- Electrical performances above expectations
- Enable new electrical architectures

but

- Challenges on cryogenic components

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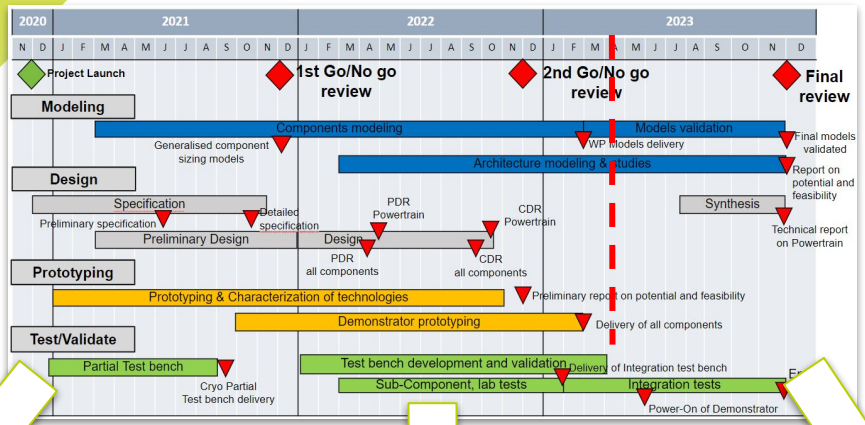
3 years - 3 steps



2021

- **Project launch**
- Team building
- Technology selection
- Partnerships
- **Specifications**

2022

- Preliminary & Detailed **Design**
- **Manufacturing**
- Partial tests
- Test bench design
- Assessment at aircraft level

2023

- Delivery & integration of Demonstrator
- **Ground tests**
- Sub-demonstrators tests
- **Final report** on feasibility & potential for aircraft

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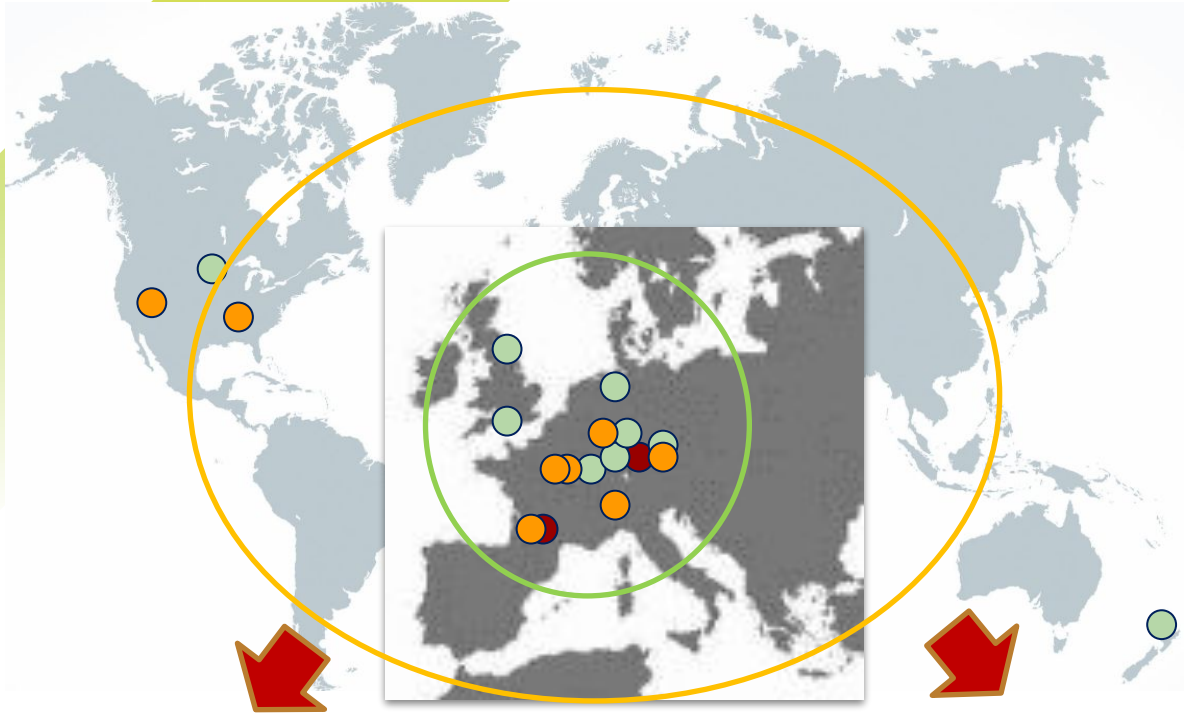
A team and an ecosystem

Airbus Academics/Institutes Companies



AIRBUS Toulouse
Distribution, cryogenic, Electric motors, tests (UpNext & CRT)

AIRBUS Ottobrunn
Power electronics (UpNext & CRT)
Tests & Modeling (UpNext & CRT & EAS)

A small team of 16 UpNext experts

&

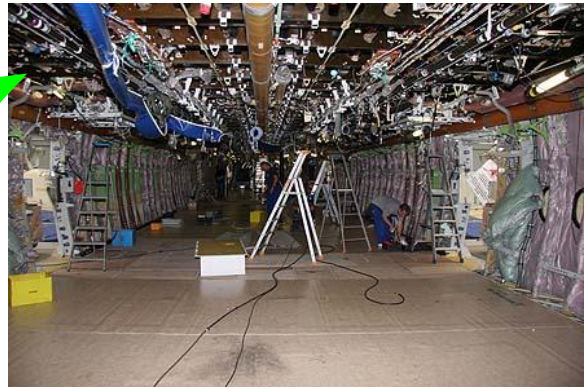
worldwide ecosystem of >30 suppliers

- Labs and Institutes
- Small companies
- Large industrial groups

Making it fly - the requirements

- Volume and weight (+ efficiency).
- Installation and maintenance
- Safety
- Reliability (~ simplicity) + redundancy (& dissimilarity)
- Fast protection reaction time (< 10 ms)
- Withstand the airborne environmental conditions
  - Vibration
  - Thermal cycles
  - etc…

Electrical route installation in A/C



What we should monitor/mitigate

- Quench in all superconducting elements (DC/AC distribution, motor)
- Correct mounting / good health of overall distribution (including contact elements)
- Mitigate fault currents (current limiter, circuit breaker) in a short time and in a safe way

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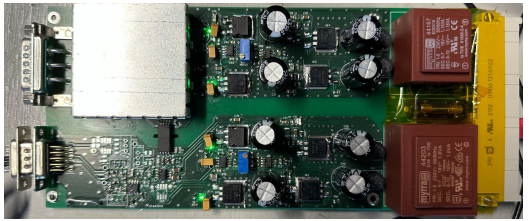
Quench detection in DC link for ASCEND

300V differential distribution

Conventional voltage measurement technique:

- Custom analog isolation board design with high gain instrumentation amplifier.
- Data processing inside FPGA (Labview)
  - Opening of Circuit breaker
- No middle point
  - Current will be ramped slowly
  - Harmonics effect is negligible



Challenge for next step:

- Need for a simple, reliable and embedded solution
- Need for compensation of higher frequencies currents
- Minimize number of measurement points (integration/manufacturing) but need for **redundancy**

A combination of voltage-based and non voltage-based technique might be required

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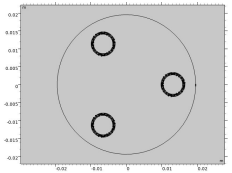
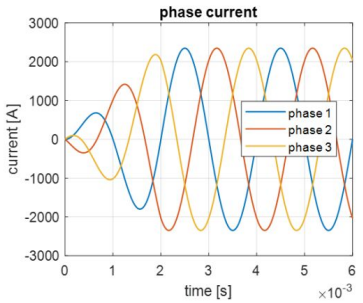
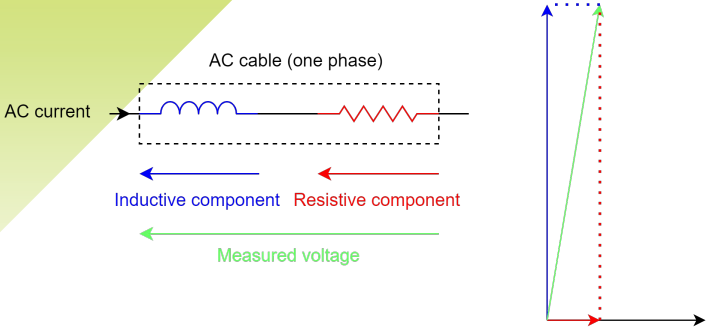
Quench detection in AC link

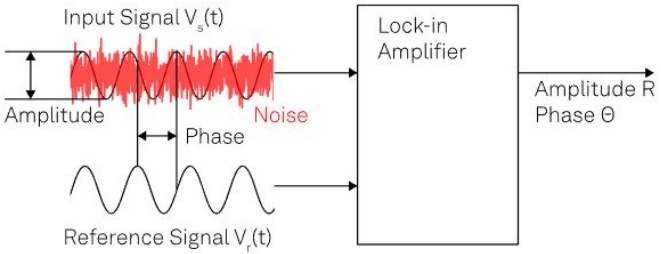
500 Hz 3 phase AC link,
1.7 kA_{RMS}





In AC operation, the voltage across the cable is dominated by its inductive component:





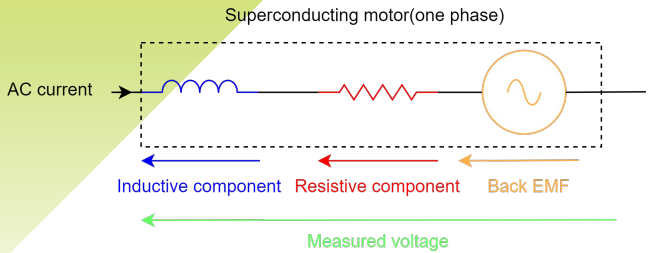
In normal operation, there can be up to four decades difference between inductive and resistive component magnitude !

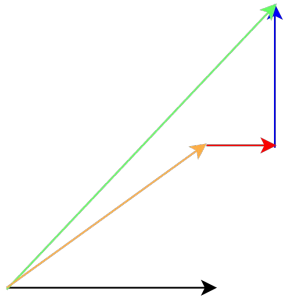
On top of that, additional noise & harmonics coming from the inverter can disturb the measurement.

Magnitude and frequencies are continuously varying according to mechanical needs.

Lock-in Amplifier is phase sensitive, it allows detecting the resistive component that is drowned into both inductive component and external noise

Quench detection in superconducting motor





For the superconducting motor it is even more challenging!

Back EMF magnitude is again one or two decade bigger than voltage inductive component.

Back EMF phase angle with resistive component is close to zero which makes lockin detection difficult

In case of superconducting rotor, voltage measurement technique might be used but the conductor is rotating.

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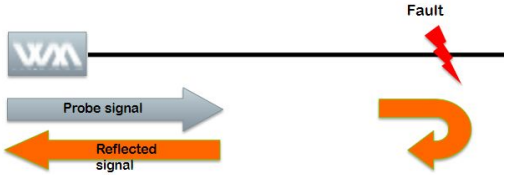
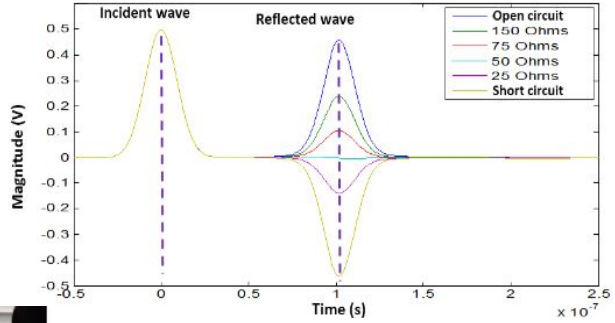
Multi carrier time domain reflectometry



Tests conducted on single tape immersed in LN2.
Fault were generated by cutting the tape or applying an external magnetic field.



Poster at ASC 2022 E. Nilsson et al.,
Fault detection in single REBCO tapes by multi carrier time domain reflectometry

MCTDR Technology

Non-intrusive diagnosis method

(signal <1V + interference management)

Embedded Technology

Compatible with the DO160

Detection of permanent and intermittent defects

Intermittent fault detection speed (300µs)

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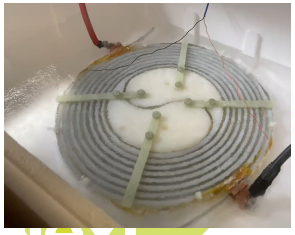
Fault current limiter

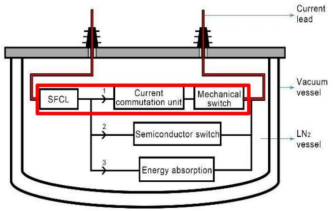
Standalone

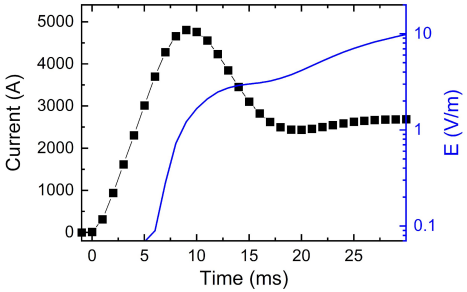
- Fault Current Limiting (FCL) capability to limit 6.8 kA overcurrent fault for 10 ms
- Stand alone SFCL bifilar coil for protection of DC link has been designed and will be tested at University of Bath.
- Cryogenic hybrid circuit breaker also under development

Embedded:

- 24 REBCO tapes wound on aluminum core, core is fully electrically insulated from the superconducting tapes.
- In fault condition the current shall redistribute from the superconducting layer to the copper plating of the HTS tapes. We aim to develop ~10 V/m within a few ms.







Summary

- Within Airbus Upnext, ASCEND is a 3 years superconducting powertrain ground demonstrator
  - The DC cable and its cooling machine are currently being integrated (first tests next week)
  - Full system will be tested by the end of november 2023
  - Subdemonstrators are also developed to explore more risky technologies

- Some diagnostic and protection functions were developed or tested in the frame of ASCEND
  - Quench detection (direct voltage measurement, lock-in under development, reflectometry)
  - Embedded / standalone FCL, cryogenic circuit breaker

- For the next steps, further challenges are to be addressed:
  - Powertrain waveforms (AC conditions, noise, harmonics)
  - Aircraft requirements (reliability, safety, manufacturing, integration, etc…)

Quench detection in aircraft superconducting powertrain will likely be based on a combination of voltage based and non-voltage based methods to provide the necessary redundancy, dissimilarity and sensitivity of detection!

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