Karlsruhe Institute of Technology

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Institute for Technical Physics

Efficient HTS DC- Cable for Power Distribution in Hybrid-Electric Propulsed Aircrafts

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With respect to a substantial reduction of greenhouse gas emission, noise and combustible consumption in aircraft an increasing interest in hybrid-electric propulsion systems has emerged in the last years. In the framework of a German research project we actually develop a HTS superconducting busbar system for DC currents able to join the different components as generator, motors and battery systems on the plane.
Main features of this busbar system are large currents at moderate voltages and in particular low-ohmic contacts, including T-type, Y-type and cross connections between system segments, this with a minimization of outer dimensions and weight. The two-pole cable consists of two stacks of REBCO-tapes. Compensation of Lorentz forces between the two poles, compensation of thermal length changes and sufficient electric insulation are the major challenges. We present details of the cable design and first test results.

Hybrid-electric propulsion systems

Details: Flightpath 2050
http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf - doi: 10.2777/50266

Aim: Reduction of carbon footprint of aviation sector, i.e.:

- 75% reduction in CO_2 emissions per passenger kilometer
- 90% reduction in NO_x emissions
- Aircraft movements are emissions-free when taxiing
- Reduction of noise emission of flying aircraft is by 65%

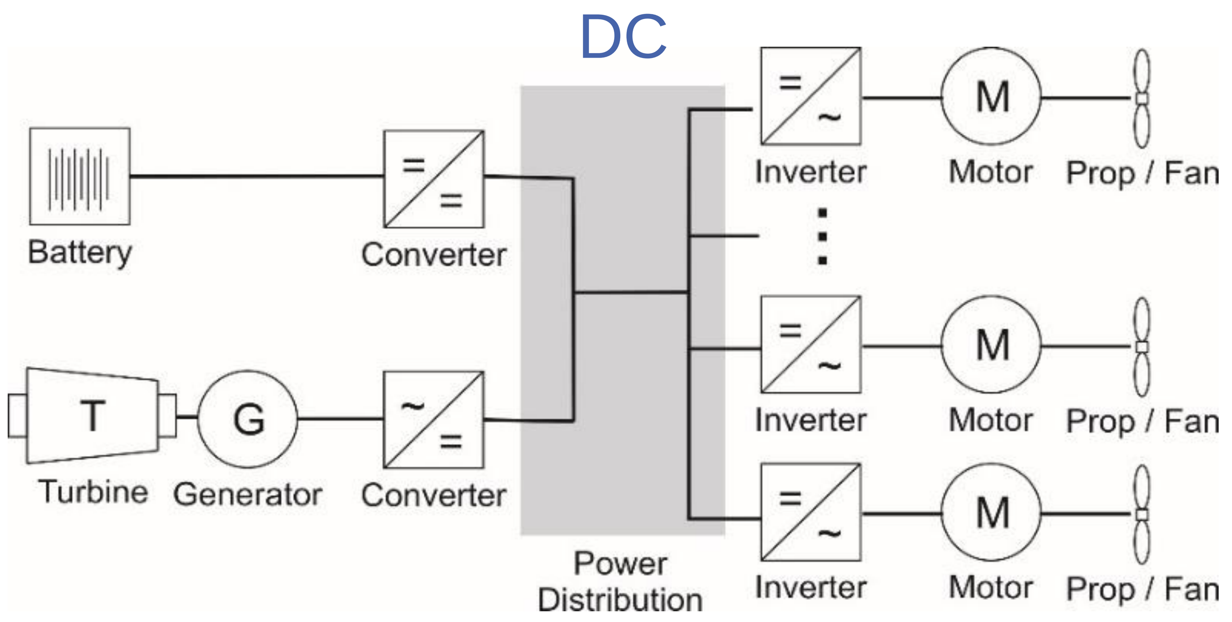
Purely electric propulsion not feasible for larger aircraft due to high battery weight
→ Combination of a gas power unit with a battery system and electric engines
→ High power-to weight ratio required
Option: Superconducting generators, motors and busbars.

Project: TELOS - Thermo-Electrically Optimised Aircraft Propulsion Systems

- Development of the technological basis for a hybrid electric propulsion system for aircraft (high power class)
- Target applications are regional range aircraft in a first step and short range aircraft in a second step (100-200 PAX)
- Funding: LuFo-V2 Program of German BMWi
- Project Duration: 01/2016 – 12/2019

Concept (see also [1]):

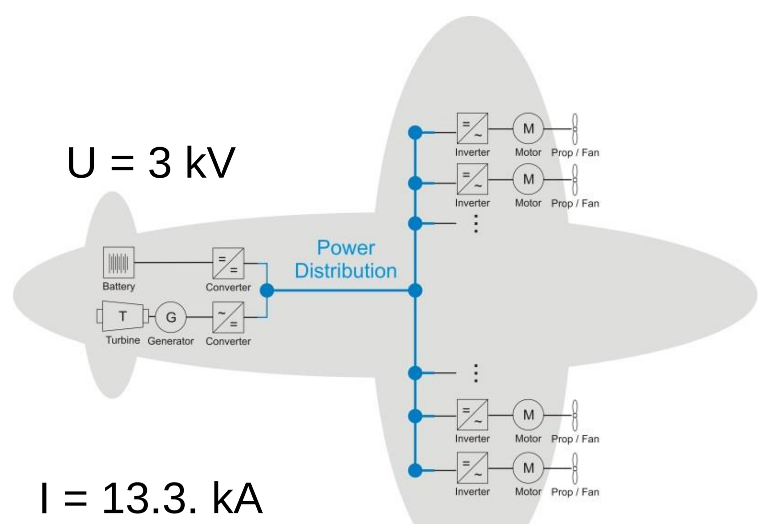
Dual use of Liquid Hydrogen (LH2) as combustible and coolant



Main challenges:

Generator, Motors: SIEMENS

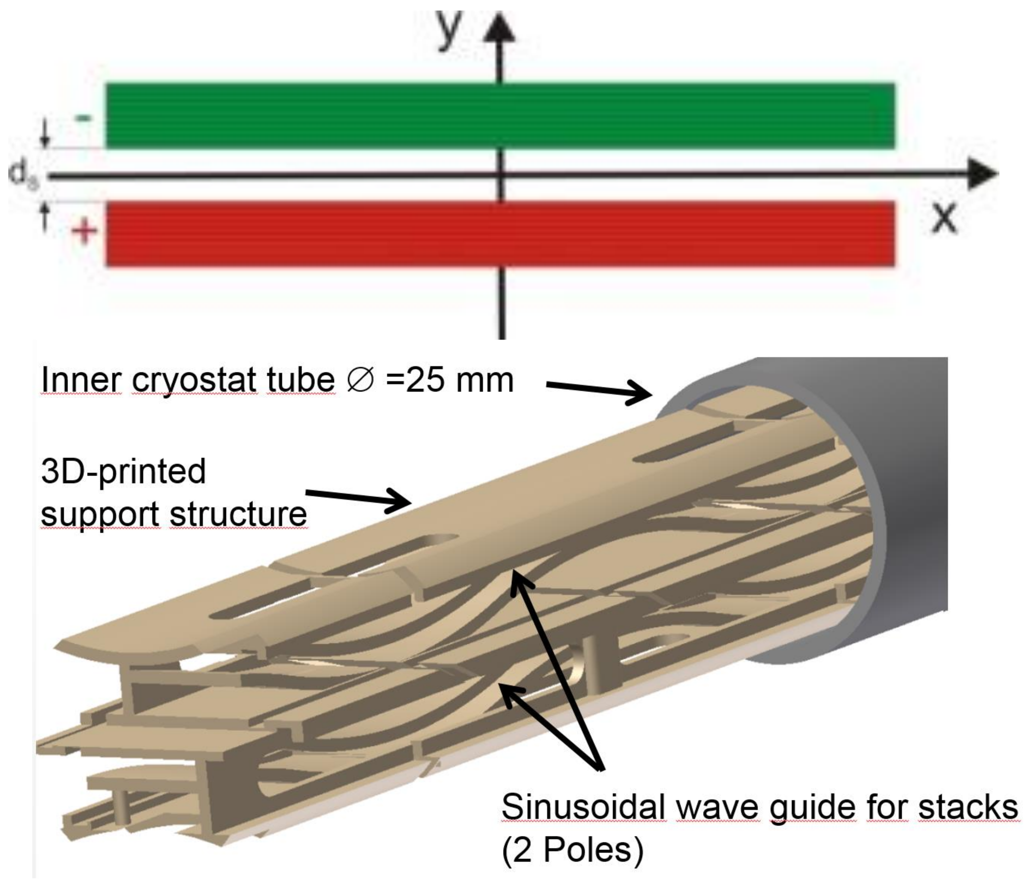
Busbar, P = 40 MW: KIT



TELOS – DC Cable Design

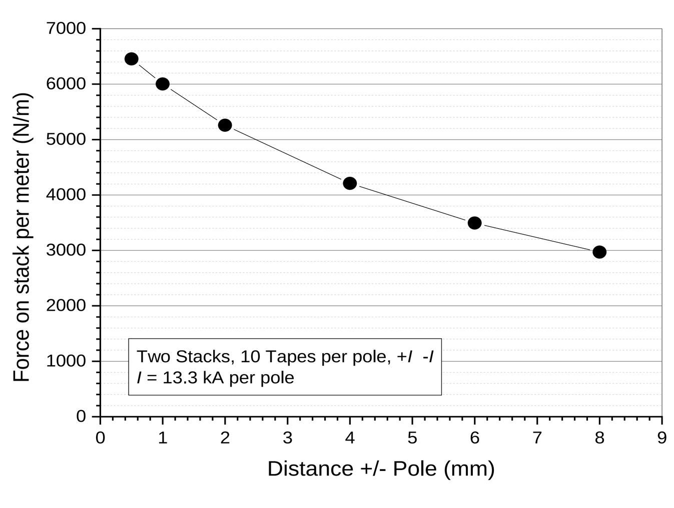
Busbar system requirements:
- Operation at 25 K (supercritical hydrogen)
- maximum length of single elements: 6 m
- Resistive losses of joint < 1 W per stack @ 13.3 kA
→ Joint resistance < 5.6 nΩ
- Compensation of thermal length changes within busbar elements
- Compensation of Lorentz-forces

Solution:
- 2-pole arrangement with 10 tapes / pole
- inner cryostat diameter 25 mm
- 3D printed PA-structure for thermal compensation

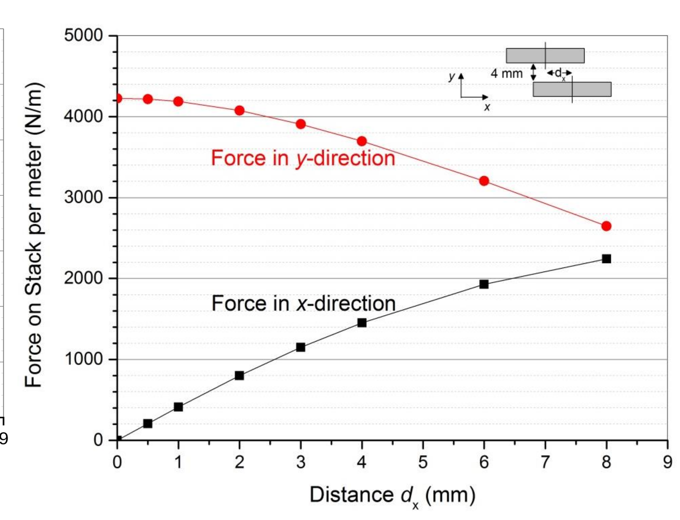


Lorentz forces :

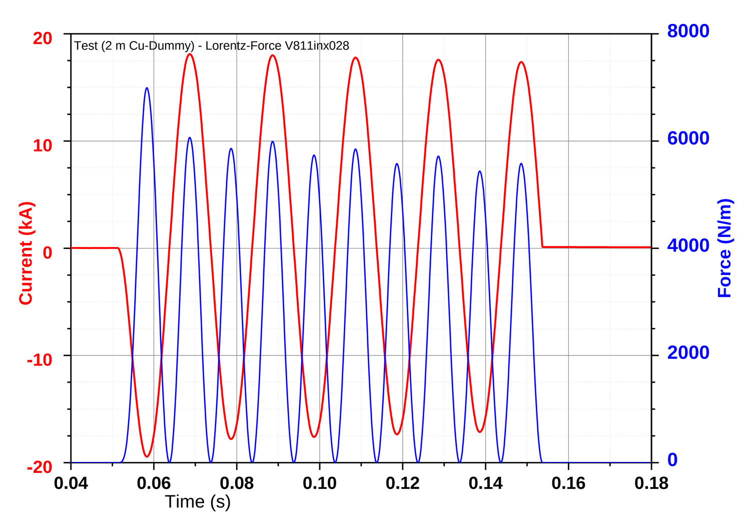
Calculated (vertical distance)



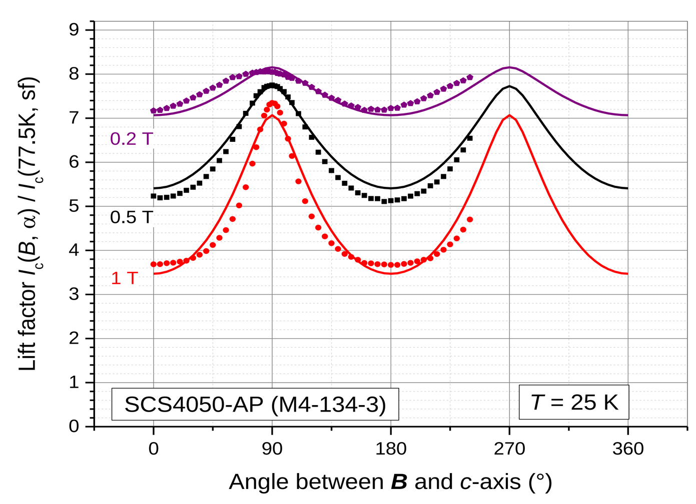
calculated (horizontal shift)



Test (Cu-dummies)



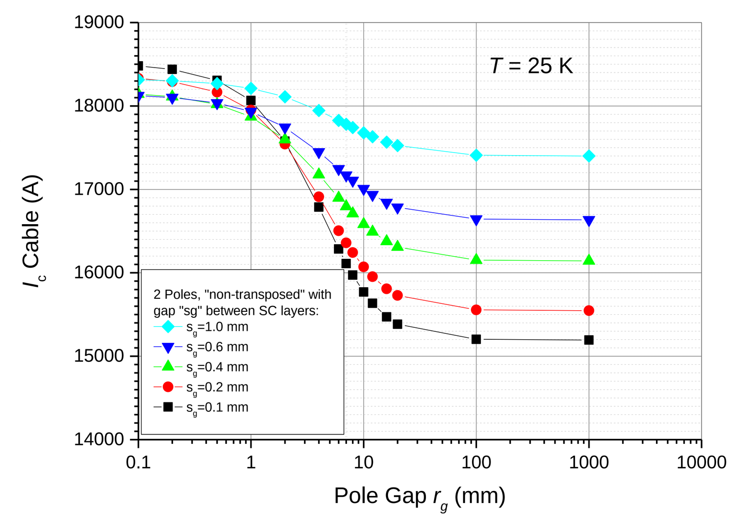
Self-field effect at T = 25 K, calculation of I_c



Fit (straight lines) with [2]

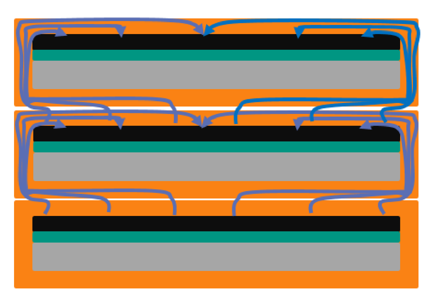
$$J_c(B_\parallel, B_\perp) = \frac{J_{c0}}{\left[1+\sqrt{(kB_\parallel)^2 + B_\perp^2}\,/\,B_c\right]^b}$$

Parameters :
J_{c0} = 1.84·10[11] A/m²
B_c = 95 T; k = 0.2; b = 85



Contacts

from / to	SL01+	SL01-	SL02+	SL02-	SL05+	SL05-	SL10+	SL10-
SL01+		33,0 nΩ	23,9 nΩ	46,7 nΩ	109,5 nΩ	92,9 nΩ	169,2 nΩ	198,2 nΩ
SL01-			55,8 nΩ	77,4 nΩ	131,9 nΩ	116,3 nΩ	195,9 nΩ	218,5 nΩ
SL02+				26,8 nΩ	94,0 nΩ	77,4 nΩ	154,1 nΩ	184,1 nΩ
SL02-					73,1 nΩ	55,7 nΩ	140,4 nΩ	167,2 nΩ
SL05+						26,7 nΩ	97,6 nΩ	124,0 nΩ
SL05-							112,1 nΩ	140,3 nΩ
SL10+								35,5 nΩ
SL10-								



Cu
REBCO
Buffer
Substrate
Cu

Total contact resistance at T = 77K .
R = 5.6 nΩ
→ P (13.3. kA) = 0.99 W

See also [3]

Conclusion:
- Cable design for 40 MVA DC cable available

Busbar concept:
- 2 poles (stacks) in one cryostat
- Lorentz-force and HV tests successful
- Joints with current redistribution and losses < 1W (@13.3 kA) available

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This work was achieved in the framework of the project Telos and granted by the German Government (BMBF, PTJ) within the Program LuFo-V2 under Grant. Nr. 20Y1516C

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KIT
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Neue Materialien Bayreuth
AIRBUS TUM SIEMENS

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