Simulation Models for Superconducting Components of the Electric Aircraft

Ali Khonya(a), Mathias Noe(a), Wescley de Sousa(a), Frederick Berg(b), Michael Cooper(b)

(a) Institute for Technical Physics (ITEP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

(b) Airbus X-Labs, Taufkirchen, Germany

Introduction and Background

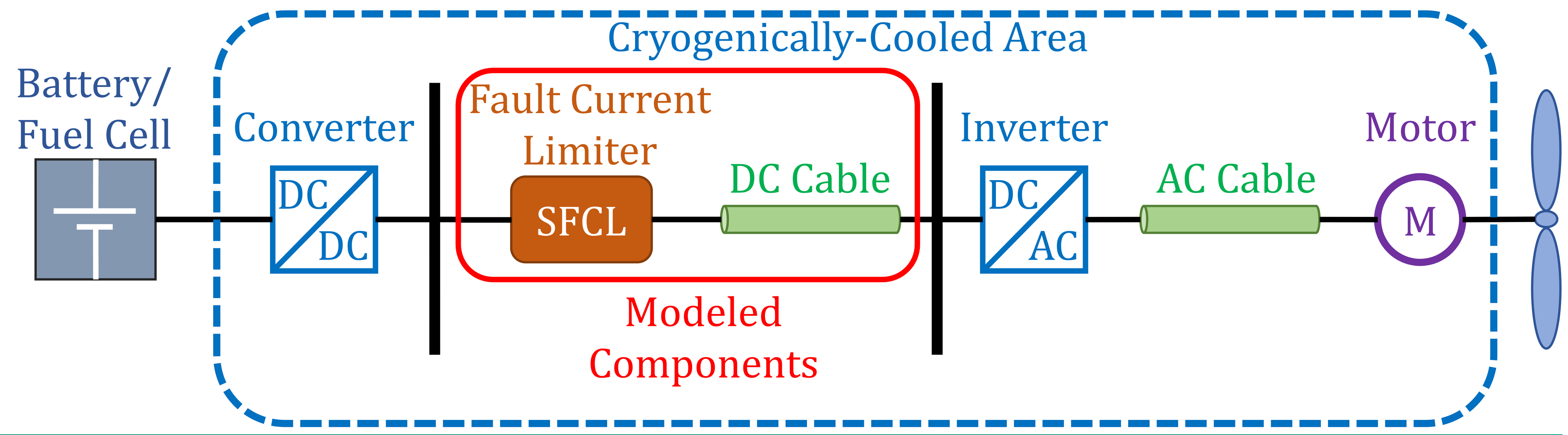
- Development of electric vehicles (road, railway, and shipping)
- 2.4% of annual CO_2 emission by aircraft in 2021
- 3.6% forecasted annual growth rate in the demand for passenger traffic

Aerospace industry goal:

- Example? EU Flightpath 2050: 75% CO2 emission reduction
- How? One potential solution: Electric Aircraft

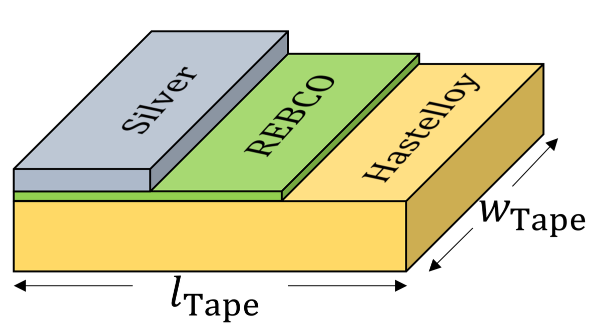
Superconducting technology advantages[1]

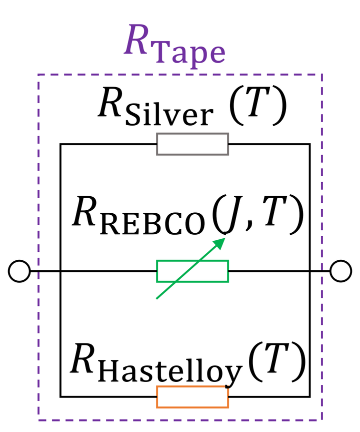
- Compactness
- Lightweight
- Higher Efficiency



Resistive Superconducting Fault Current Limiter (RSFCL)

A) Electrical characteristic [2] → Resistance and current





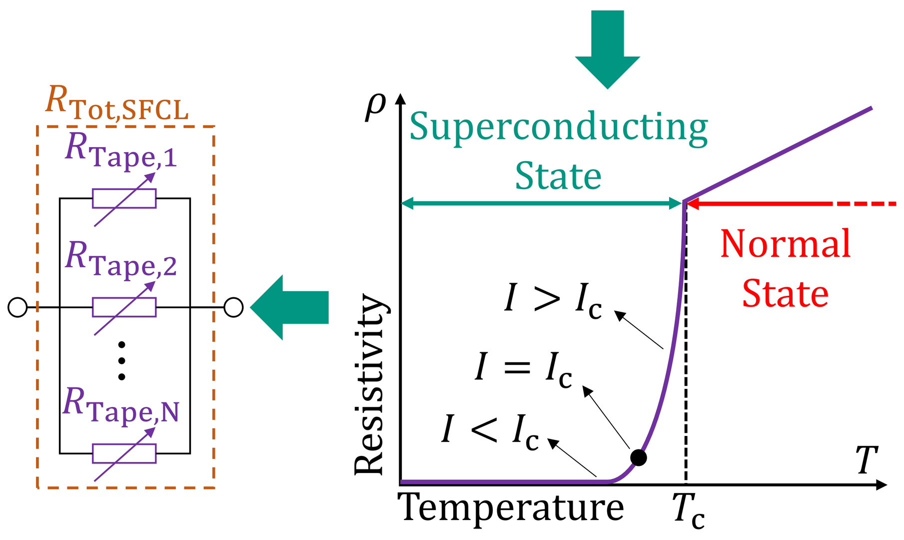
$I_{nom} = 1.5$ kA

$I_{c,Tape} = 550$ A

3 HTS Tapes

LN_2 @ 77 K

$l_{Tape} = 8.5$ m

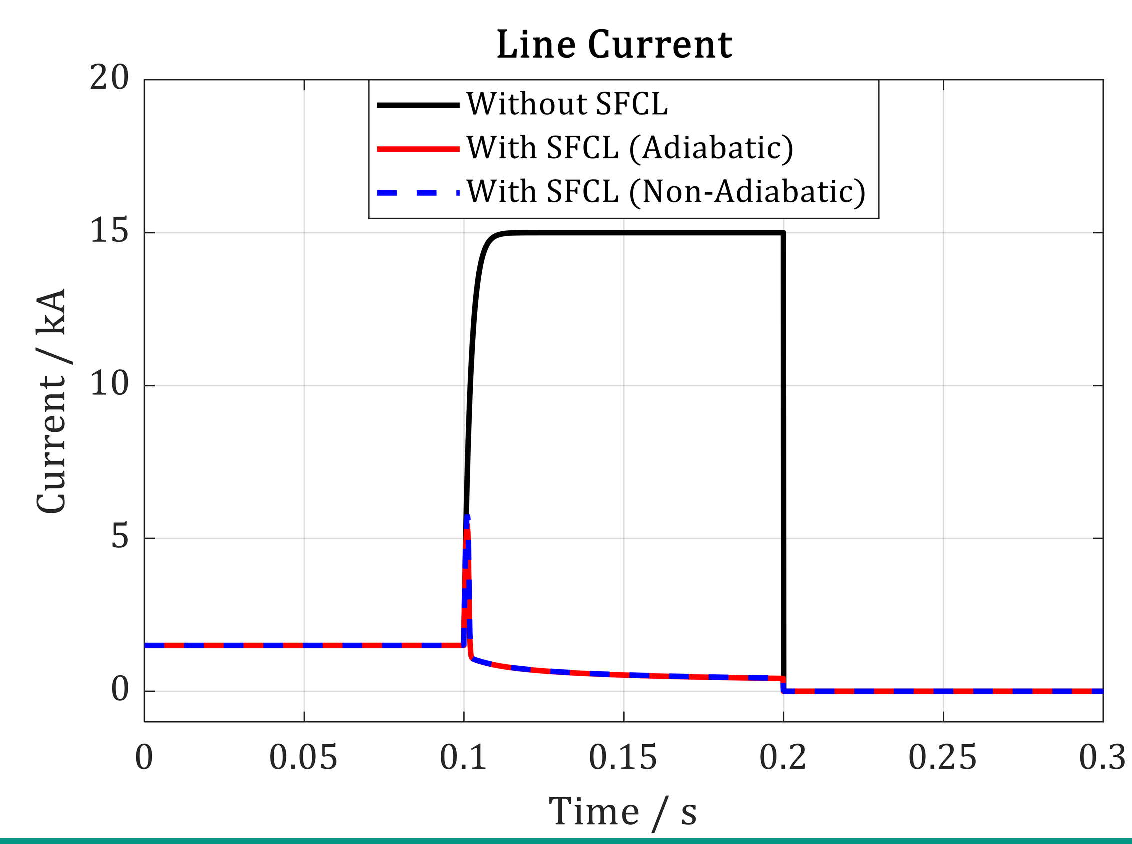


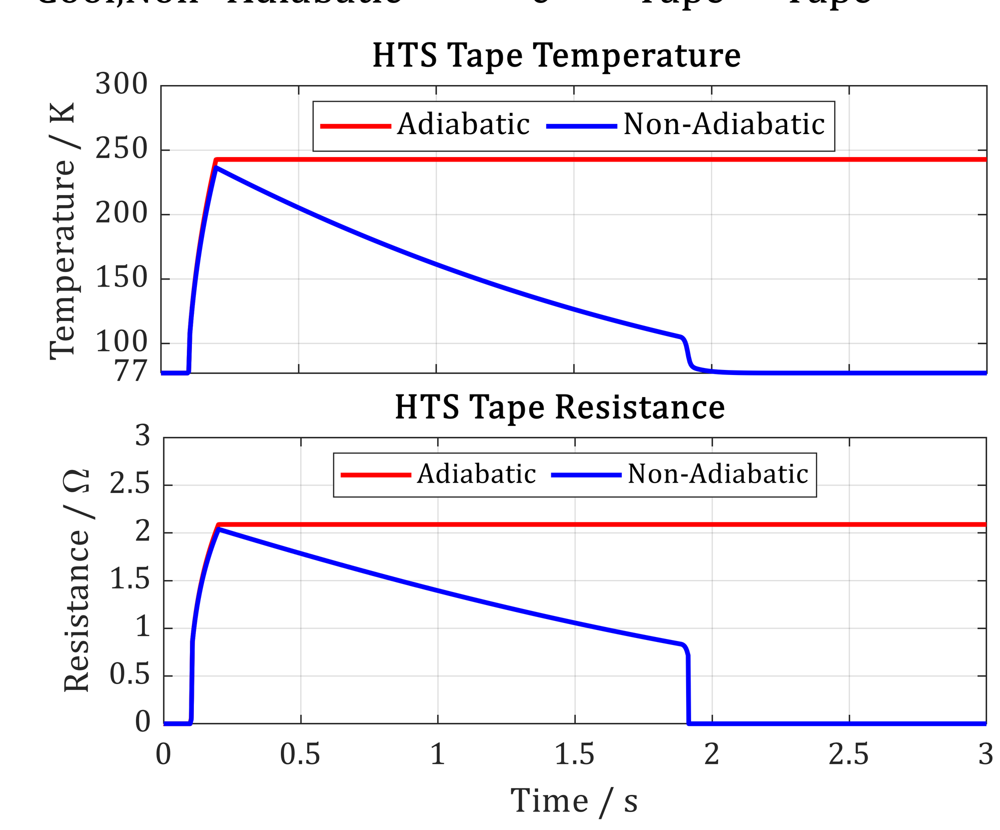
B) Thermal characteristic [2] → Temperature

$$C \cdot \frac{\partial T}{\partial t} = P_{Loss} - P_{Cool}$$

$$P_{Loss} = R_{Tape} \cdot I_{Tape}^2 \qquad P_{Cool,Adiabatic} = 0$$

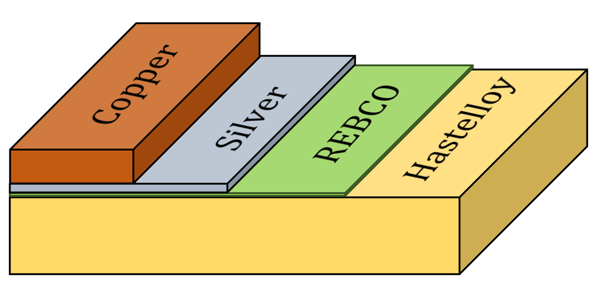
$$P_{Cool,Non-Adiabatic} = 2h_c \cdot w_{Tape} \cdot l_{Tape} \cdot \Delta T$$





Superconducting DC Cable

Temperature calculation similar to RSFCL



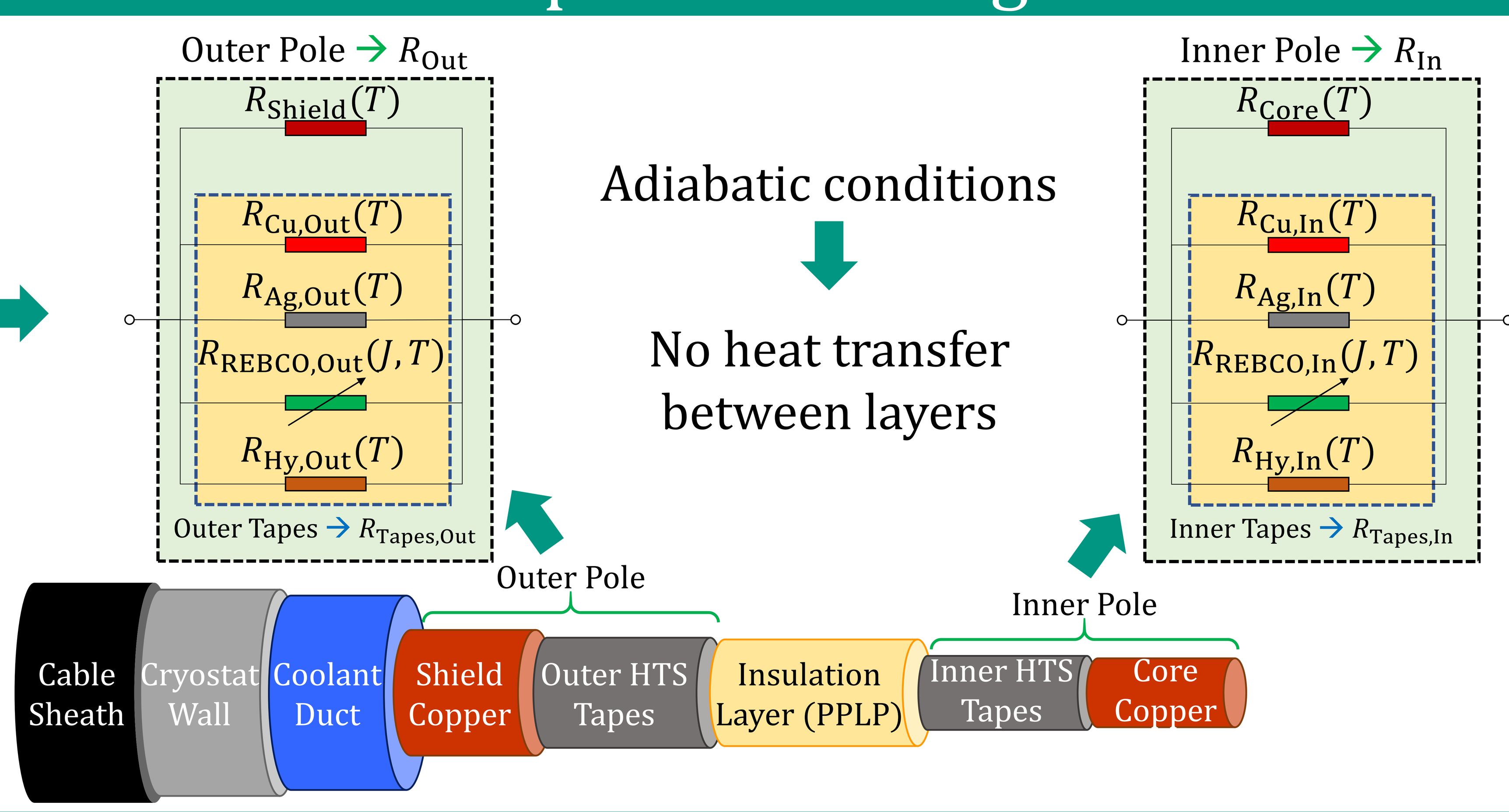
$I_{nom} = 1.5$ kA

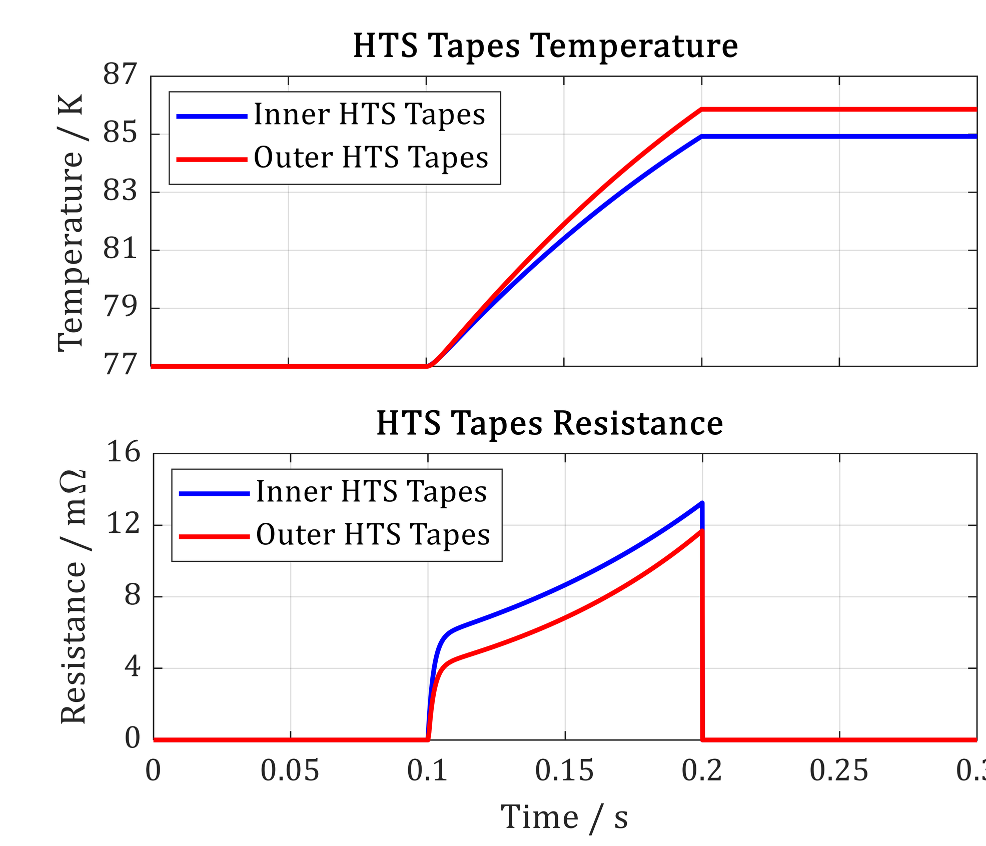
$I_{c,Tape} = 200$ A

8/12 Inner/Outer HTS Tapes

LN_2 @ 77 K

$l_{Cable} = 50$ m

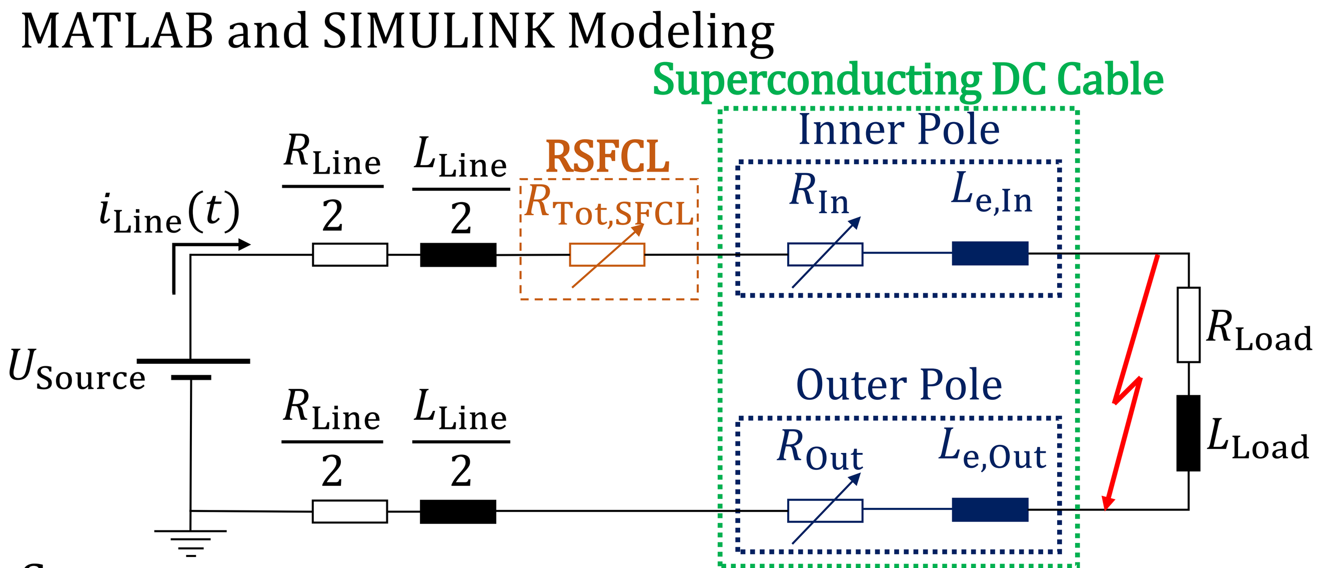


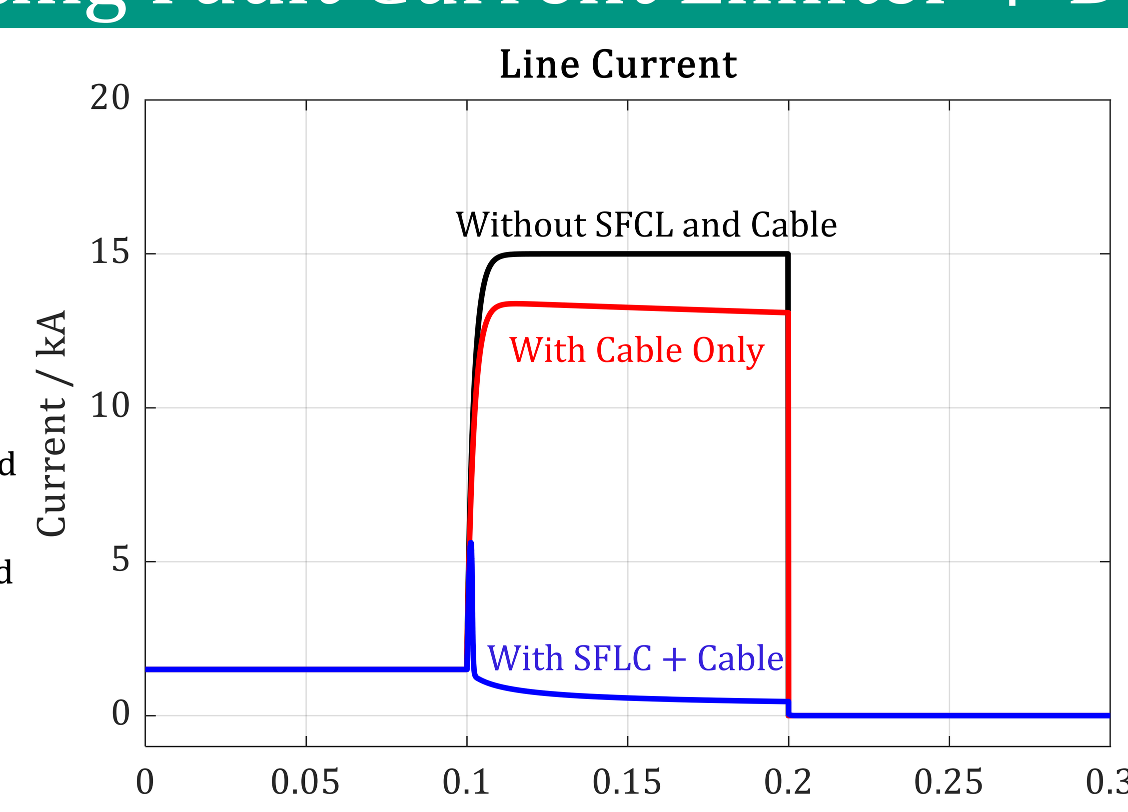


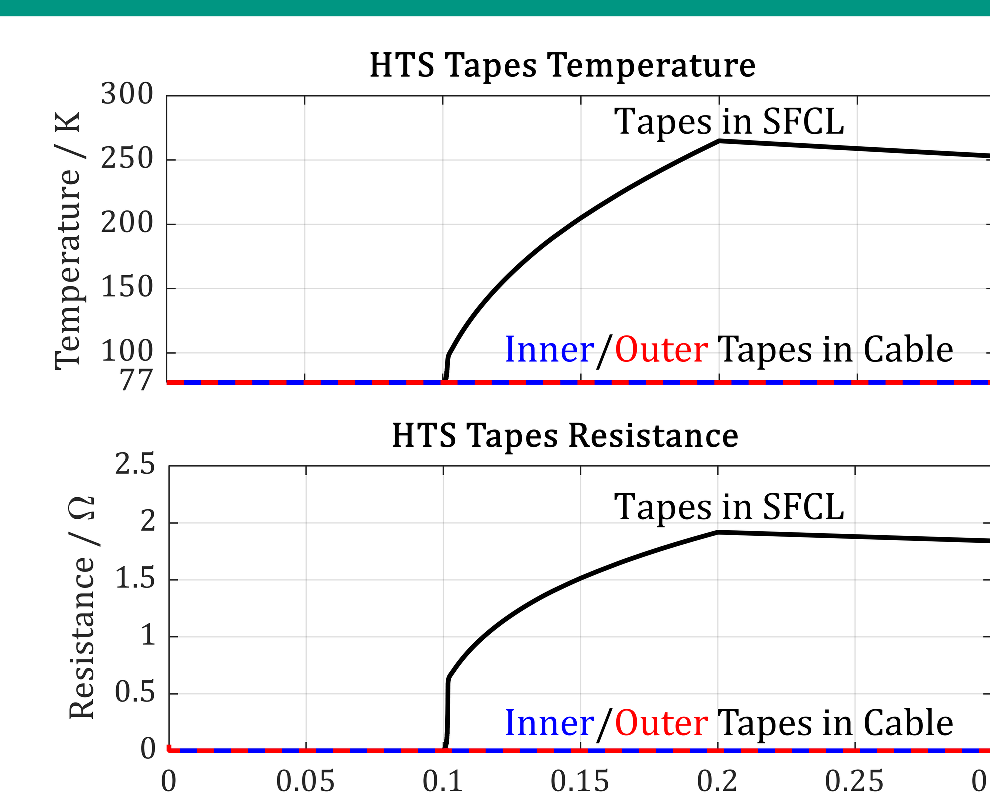
Superconducting Fault Current Limiter + DC Cable

Short-Circuit Behavior Analysis

MATLAB and SIMULINK Modeling







Summary:

- Lumped-parameter modeling of the RSFCL and cable
- Configurable SIMULINK models for RSFCL and cable

References:

[1] L. Ybanez et al., "ASCEND: The first step towards cryogenic electric propulsion", doi: 10.1088/1757-899X/1241/1/012034.

[2] W. T. B. de Sousa, "Transient Simulations of Superconducting Fault Current Limiters," Ph.D. Dissertation, Federal University of Rio de Janeiro, Brazil, 2015.