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Simulation of the Thermal Performance of HTS Coated Conductors for HVDC SFCL

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Introduction

In this work we investigate the thermal performance of the HTS conductor design proposed within the FastGrid project by comparing it with HTS tapes frequently described in the literature. Our goal is, by means of numerical simulation, to determine the best thermal behaviour between different HTS conductors.

HTS Coated Conductors

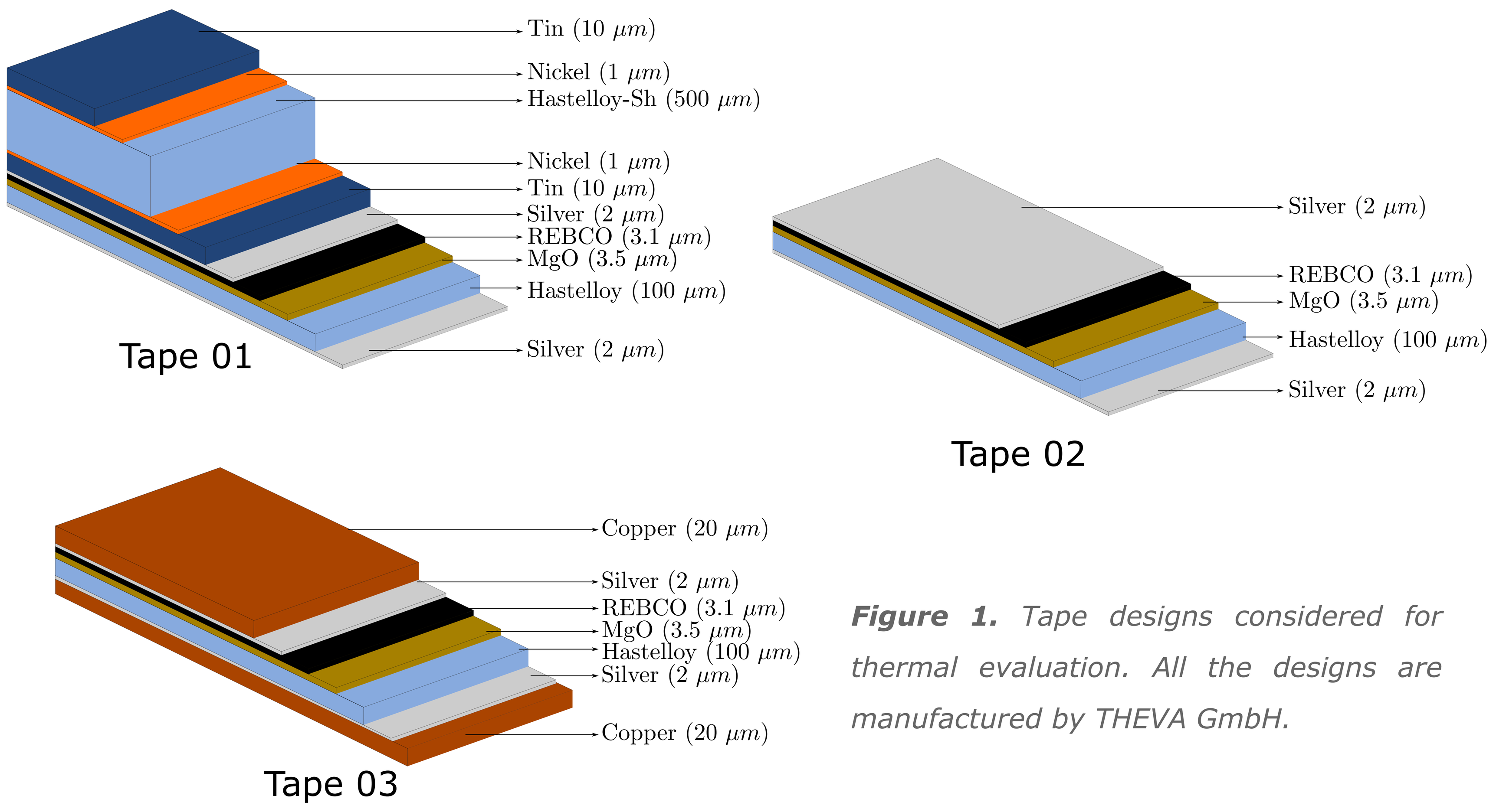

Figure 1. *Tape designs considered for thermal evaluation. All the designs are manufactured by THEVA GmbH.*

Simulation Model

A DC voltage source in series with a R-L load and the HTS conductor.

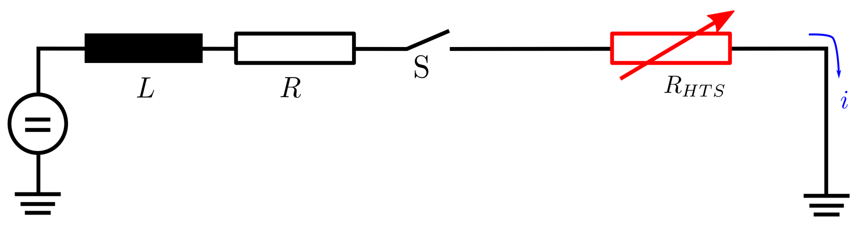

Figure 2. *Electrical Circuit for simulation.*

The simulations are developed in two dimensions considering the Fourier-equation for heat conduction.

$$dc\frac{\partial T(x,y,t)}{\partial t} = k\left[\frac{\partial^2 T(x,y,t)}{\partial x^2} + \frac{\partial^2 T(x,y,t)}{\partial y^2}\right] + \dot{g}$$

This equations was solved numerically by means of the FDM based on the ADI routine. In the first half-timestep:

$$dc\frac{T_{i,j}^{t+\frac{\Delta t}{2}} - T_{i,j}^{t}}{\Delta t/2} = k\left[\frac{T_{i,j-1}^{t+\frac{\Delta t}{2}} - 2T_{i,j}^{t+\frac{\Delta t}{2}} + T_{i,j+1}^{t+\frac{\Delta t}{2}}}{\Delta x^2} + \frac{T_{i-1,j}^{t} - 2T_{i,j}^{t} + T_{i+1,j}^{t}}{\Delta y^2}\right] + \dot{g}$$

In the second half-timestep;

$$dc\frac{T_{i,j}^{t+1} - T_{i,j}^{t+\frac{\Delta t}{2}}}{\Delta t/2} = k\left[\frac{T_{i,j-1}^{t+\frac{\Delta t}{2}} - 2T_{i,j}^{t+\frac{\Delta t}{2}} + T_{i,j+1}^{t+\frac{\Delta t}{2}}}{\Delta x^2} + \frac{T_{i-1,j}^{t+1} - 2T_{i,j}^{t+1} + T_{i+1,j}^{t+1}}{\Delta y^2}\right] + \dot{g}$$

Results

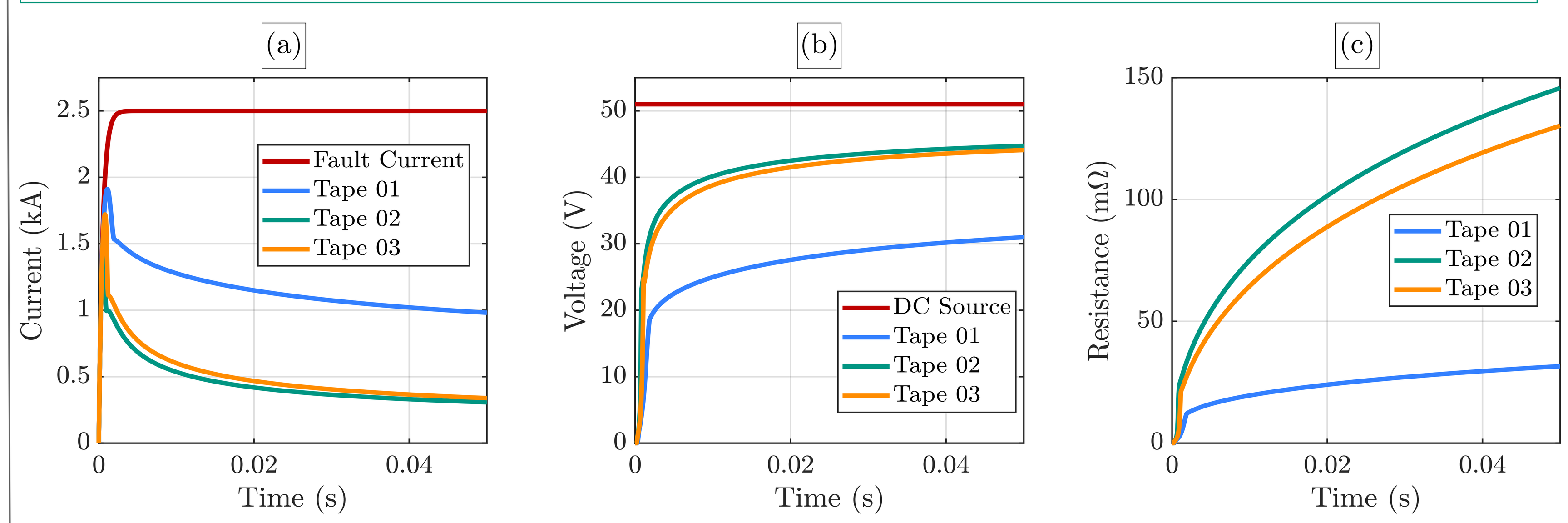

Figure 3. *Comparisons of the simulated results for each tape design.*

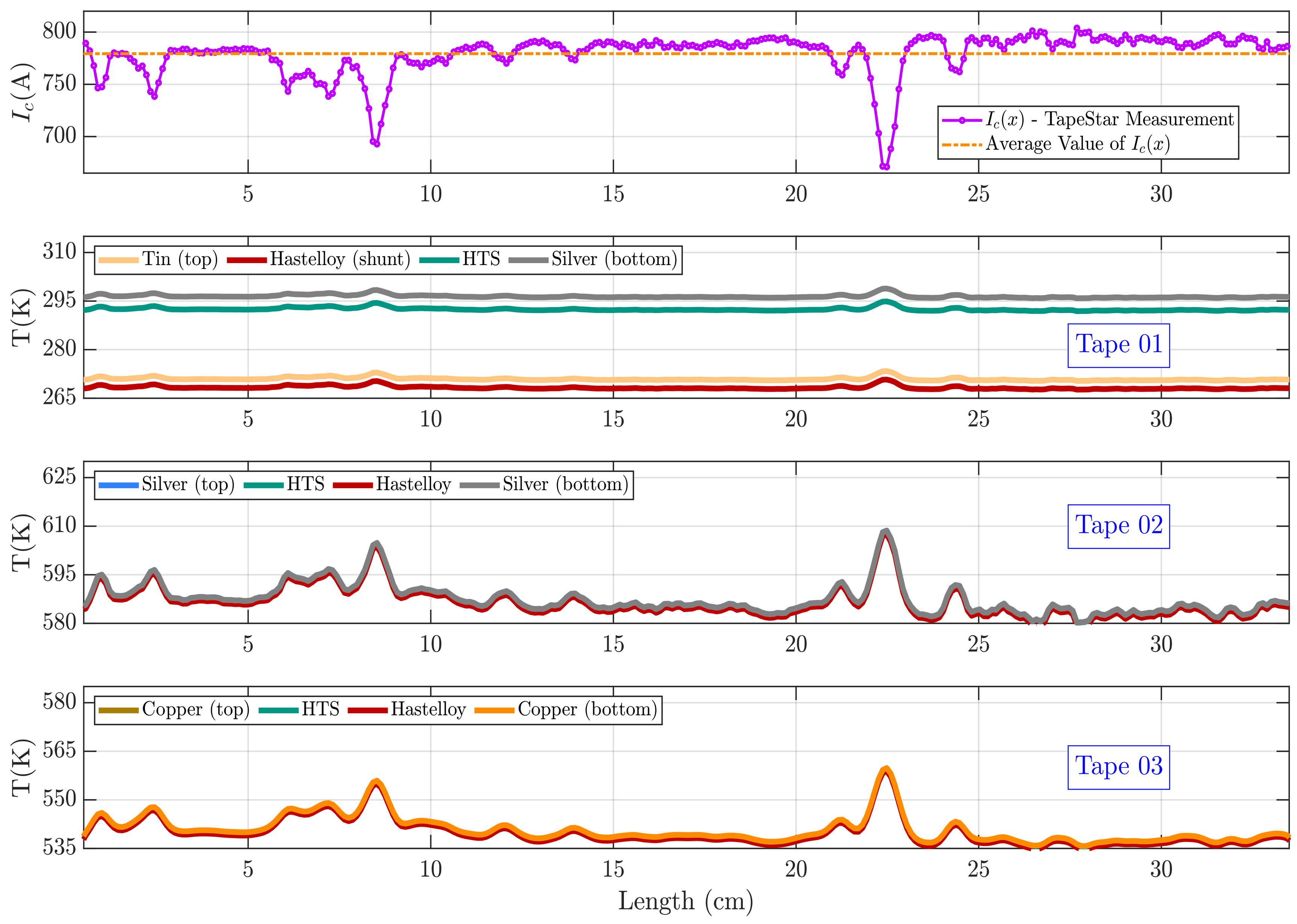

Figure 4. *Temperature along length for each tape after the fault period.*

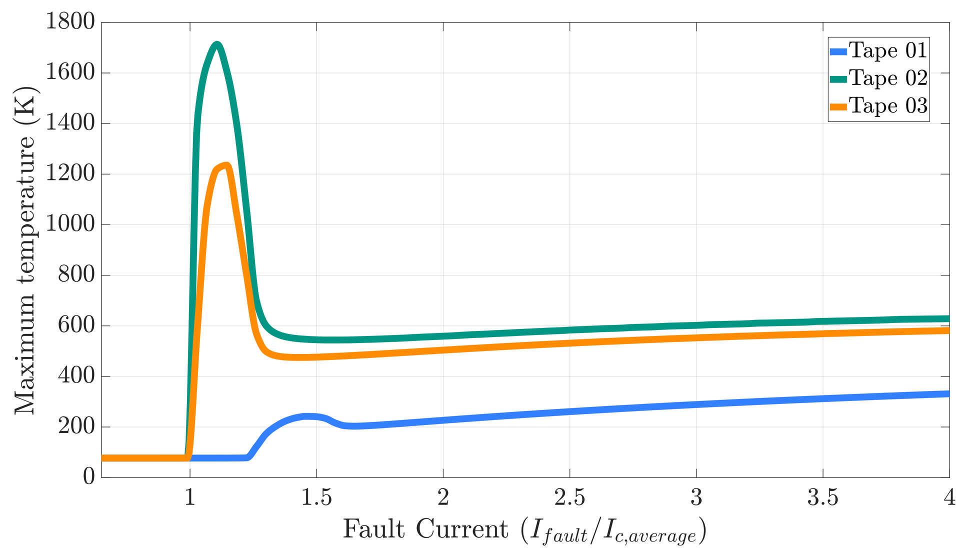

Figure 5. *Calculated maximum temperature values at the end of the fault period (50 ms) versus applied prospective fault current (in relation to $I_{c,av}$=780 A).*

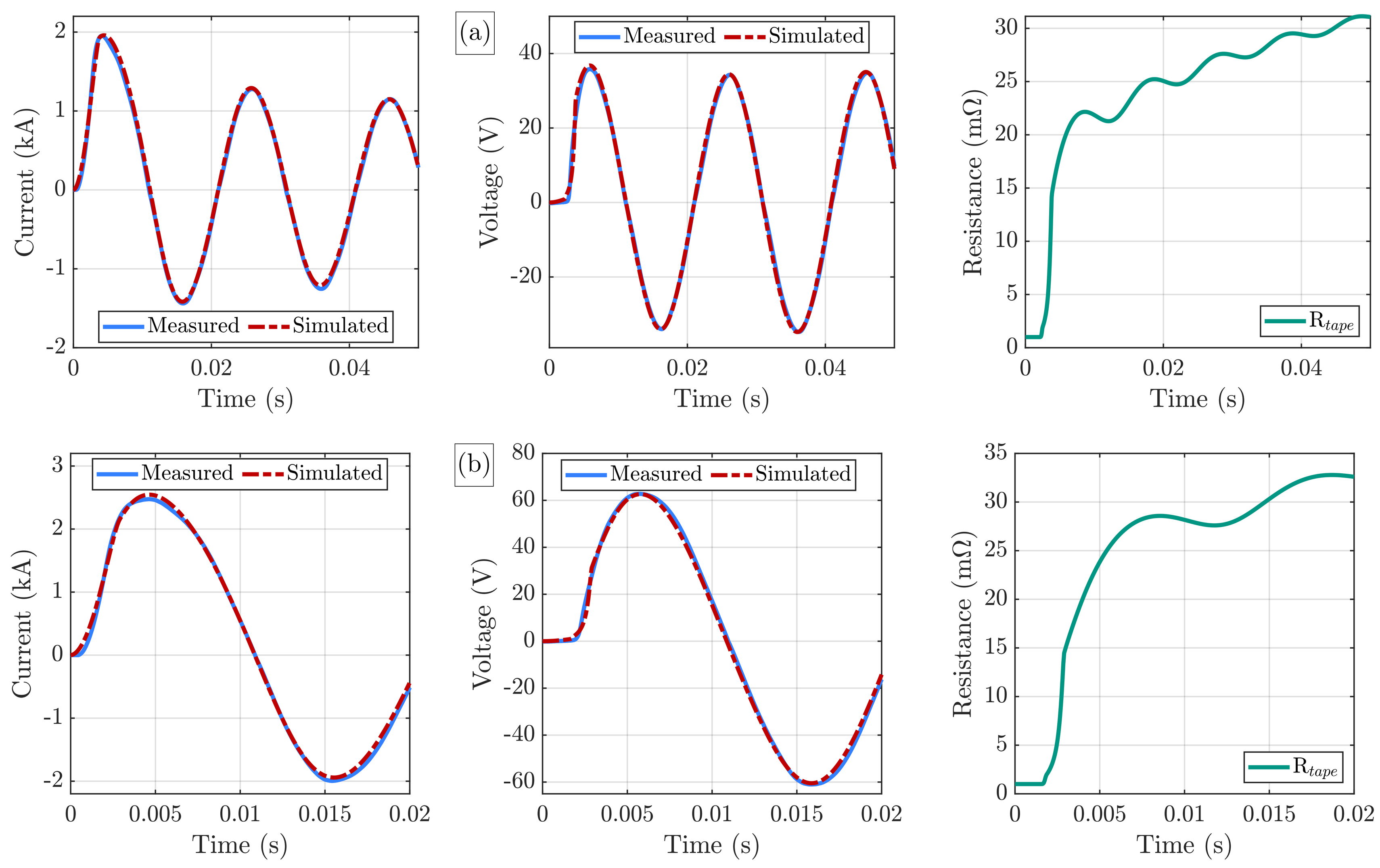

Figure 6. *Comparison between experiments and simulations for (a) 85 V/m and (b) 150 V/m.*

Conclusions

We can conclude that the design Tape 01 is more indicated to withstand DC voltages of 150 V/m, since its thermal behaviour can be considered more effective when compared to the designs of Tape 02 and Tape 03.

Although Tape 02 and Tape 03 yield to a better limitation factor, such designs may fail if the fault current lies between $1.0xI_{c,av}$ and $1.5xI_{c,av}$. In this range, the observed temperature values would lead to a complete destruction of the HTS conductor.

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