Heat Propagation Improvement in YBCO-Coated Conductors for Superconducting Fault Current Limiters
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Introduction:
In order to engineer high-temperature superconducting cable applications, such as YBCO-based CCs for RSFCLs, the adequate protection from their quench damages represents one of the crucial parameters [1]. For that reason one must properly model and construct such devices using, for example, FEM numerical simulations and various deposition thin film techniques, respectively, as is given in this contribution. Its objective is to improve the thermal stability in RSFCL devices by homogenizing heat dissipation, as well as, to optimize their designs in order to guarantee their safe integration in medium-voltage grid configuration.

Results:
We present the computational results (Tab. 1) of the two NZPV components (Fig. 4) obtained for the following parameters: δ0,h=40 nm, δYBCO=300 nm, δMgO=2 μm, δlast=1 μm, δCu=1-5 μm, δSiO2=90 μm, Jc=2 MAcm⁻², Jv=2.5 MAcm⁻², and f=300 WK⁻¹cm⁻², 3D geometry of three lines (each 6x20 mm²), with the separation of 0.4 mm (Fig. 4), was meshed extrusively due to the multi-structured anisotropy. The mesh follows the condition delineated in Figure 5. The model was successfully validated with available experimental data for sapphire and hastelloy substrates.

Computational Method:
The heat transfer time dependent simulations were carried out on a simple 3D meander geometry (Fig.1). The heat source was implemented as a T-J dependent power density function, evaluated numerically in R from the so-called current sharing function (see Figures 2 and 3 below). It assumes the following form of the YBCO resistivity:

$$\rho(J,T) = \rho_0 \left( \frac{J}{J_c} \right)^{n} \text{ with } J_c(T) = J_{o\text{c}} \left( 1 + \frac{T}{T_c} \right)^{1/n} \left( 1 - \left( \frac{T}{T_c} \right)^{1/n} \right)^{1/n}$$

Normal Zone Propagation Velocity (NZPV) was computed in COMSOL Multiphysics® directly as a first derivative of the expected value of spatial coordinate along the line (0<x<L), for which the Gaussian density distribution peak around T(x)=TNZ guarantees the highest probability. The line-width of the density function (δ) was controlled with the size of the projected mesh element (h) in order to ensure the smoothness of the generated <x(t)> function.

$$v_{NZP} = \frac{\delta}{\delta t} \int_{x=0}^{L} x e^{\frac{(T(x)-T_{NZ})^2}{2\sigma^2}} dx$$

$$T_{NZ} = T_c = 92 K, h \times x_0 < \delta << T_{NZ}$$

Conclusions:
In conclusion, the FEM model, which we have developed in COMSOL's Heat Transfer Module, has been found quite accurate to simulate the 3D transition-induced heat propagation in YBCO-based CCs used for RSFCLs with a simple meander geometry on a novel multi-structure (the left). For superconducting CCs, there are various designs of the generated <x(t)> function.

Table 1. The longitudinal (υc) and lateral (υl) NZPVs values with respect to the Cu thickness (δCu).

<table>
<thead>
<tr>
<th>δCu [μm]</th>
<th>υc [m/s]</th>
<th>υl [m/s]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>4.50±0.05</td>
<td>4.0±0.1</td>
</tr>
<tr>
<td>2</td>
<td>4.60±0.05</td>
<td>4.0±0.2</td>
</tr>
<tr>
<td>3</td>
<td>4.65±0.05</td>
<td>4.0±0.2</td>
</tr>
<tr>
<td>4</td>
<td>4.70±0.05</td>
<td>4.1±0.3</td>
</tr>
<tr>
<td>5</td>
<td>4.70±0.05</td>
<td>4.1±0.3</td>
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References: