Plan for a PhD thesis at KIT - Institute for Technical Physics

Candidate: Roland Gyuraki
Thesis director: Prof. Dr.-Ing. Mathias Noe
Supervisor: Dr. Francesco Grilli
Title: Investigation of quench dynamics in high-temperature superconductor tapes and assemblies
Period: January 2016-December 2018 (36 months)

Expected scientific output of the thesis project

1. **Assessment of the thermal stability of striated tapes.**
2. **Development of numerical models for quench of different complexities (2-D and 3-D FEM and 1-D/2-D equivalent circuits).**
3. **Measurement of NZPV in complex HTS cable geometries (e.g. Roebel) to assess their stability in a variety of working conditions.**

Background and motivation

With the term *quench* one denotes the process occurring in a superconducting device when any part of it goes from the superconducting to the normal state: because of the high values of the normal-state resistivity and of the high current densities, this causes an intense local heating (ρJ^2), which takes the quench point and the surrounding regions to temperatures above the critical one. It is of paramount importance that the device and the composing conductors are designed in a way such that they are able to quickly return to the superconducting state, before any irreversible damage is done. In other words, that they are stable against any disturbances that can cause quench.
The very rapid increase of the superconductor's resistance at currents beyond the critical one can be used for building applications such as resistive superconducting fault current limiters, which are used to protect electric grids. These devices normally operate at sub-critical currents, so in the grid they are electrically "transparent" in the sense that they impedance is very low. When a fault occurs, the impedance of the device increases very rapidly and this fact can be used to prevent a very high current to flow in the grid. For the device to be effective it is important that the quench propagates quickly through the superconductor, otherwise the energy concentrated in a limited area can easily lead to burning and destroying the superconducting tape. In order to design correctly sized devices, it is therefore very important to be able to quantify the *normal zone propagation velocity* (NZPV) i.e. the speed at which the quench propagates in the tapes (for FCL applications).
The knowledge of the quench dynamics and of the normal zone propagation velocity are important not only in tapes for FCL applications, but also in more

complex tape assemblies such as Roebel cables. The latter are high-current cables composed of intertwined meander-shaped strands, with high potential for applications such as magnets, motors/generators, and transformers. At present very little is known on the quench propagation in these assemblies, and this kind of cables will be investigated in the second part of the thesis, once the measurement techniques are developed for single tapes.

In short, the current thesis projects aims at measuring this speed in different tape and cable architectures, using different techniques to induce the quench, with the aim of providing solutions for designing efficient and thermally stable HTS devices. For this purpose, the candidate will also use specifically developed numerical models to interpret the results of the measurements.

Work plan

TASK 1: Literature review on the state-of-the art

In the first months of PhD thesis, the candidate will perform a thorough literature review both on the experimental techniques and numerical modeling of quench dynamics. The topic "quench dynamics" is vast, and it is important to have a precise idea of the state-of-the-art and to sift through the numerous publications to identify most suitable approaches – but experimental and theoretical – for the tape and cable structure under investigation in this thesis project. The acquired knowledge could also serve as basis for a possible future review article.

TASK 2: Investigation of quench dynamics in HTS tapes

The goal of this task is to set-up an experimental apparatus for the measurement of quench dynamics in individual HTS tapes. The experimental set up will be configured to study situations typical of different applications. In particular, "slow" normal zone propagation (magnets) and very fast propagation (fault current limiters). The quench will be induced either with different methods (heater, magnetic flux, laser-induced hole in the tape). The quench propagation will be monitored with electrical measurements (voltage taps) and visual methods (high-speed camera). The latter can be particularly useful for studying the dynamics of re-cooling, when the sample recovers toward the superconducting state. The quench investigations will be extended to striated tapes as well, which will allow assessing the reliability of the striation process in practical applications. The latter is a topic that has not been explored in the literature yet.

TASK 3: Numerical models for quench dynamics of HTS tapes

This tasks aims to develop numerical models for the quench dynamics in HTS tapes. The models simulate the presence of all the layers typically present in a HTS coated conductor (superconductor, substrate, stabilizer) and will be implemented in different numerical frameworks: 2-D and 3-D electro-thermal models with finite-element and 1-D/2-D equivalent electric circuits.

TASK 4: Investigation of quench dynamics in HTS assemblies (cables)
Quench measurements will be extended from individual tapes to cables such as Roebel and/or CORC. One of the challenges will be to induce the quench in a particular strand of the cable. Normal zone propagation velocity measurements will be performed. Numerical models from TASK 2 will be used to interpret experimental data.

TASK 5: Thesis writing (month 31-36)
This period will be dedicated to the writing of the PhD thesis.