Experimental Design for Testing Current Redistribution in a REBCO Tape-Stack Cable

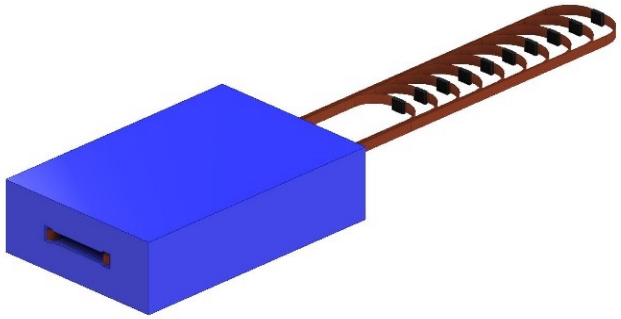
John Rogers[1,2], Peter McIntyre[1,2]

[1]Texas A&M University, [2]Accelerator Technology Corp.

Abstract

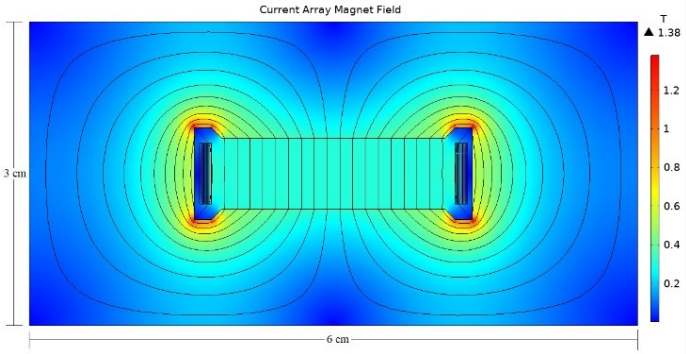
Recent theoretical studies have suggested the feasibility of using a non-insulated, non-transposed REBCO tape-stack cable in a high-field magnet winding. Variation in magnetic field across the tape-stack induces a different critical current for each tape. As the tapes approach critical operation, the dynamic rise in resistivity drives currents to redistribute thus preventing premature quench and optimizing the cable current capacity. A lumped network circuit model coupled with magnetic field simulation has been studied to predict the behavior of current redistribution in such a cable. An experimental design and simulations are presented to test for current redistribution at liquid nitrogen temperatures. Simulations demonstrate that, if predictions given by the circuit model are accurate, current redistribution will be experimentally verified. Fabrication and operation of the planned experiment is detailed including structural, material, electrical, and magnetic design.

Conceptual Experiment

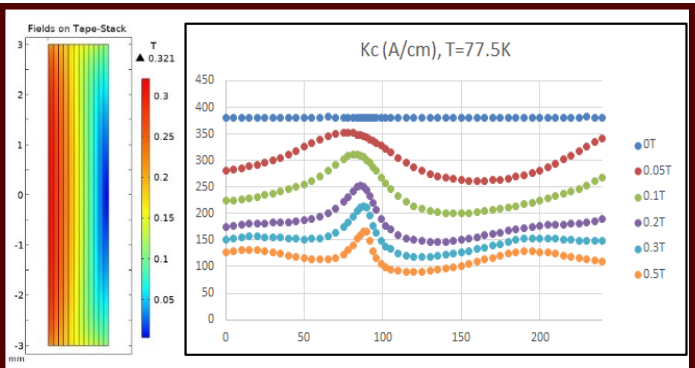


Conceptual design of a small scale dipole for testing current redistribution in a REBCO tape-stack cable. Magnetic field is generated in the bore of the steel flux return by straight lengths of tape-stack cable. On the tail-end, returning tapes are spaced apart and equipped with Hall sensors to measure the current flowing through each tape individually.

Magnetic Simulation



Magnetic field in the current array dipole at an operating current of 1700 A.



Tape	1	2	3	4	5	6	7	8	9	10	11	12
I_c (A)	115	118	122	125	129	135	140	148	155	164	172	179

Variation in magnetic field across the tape-stack induces a different critical current for each tape in the cable.

Circuit Model

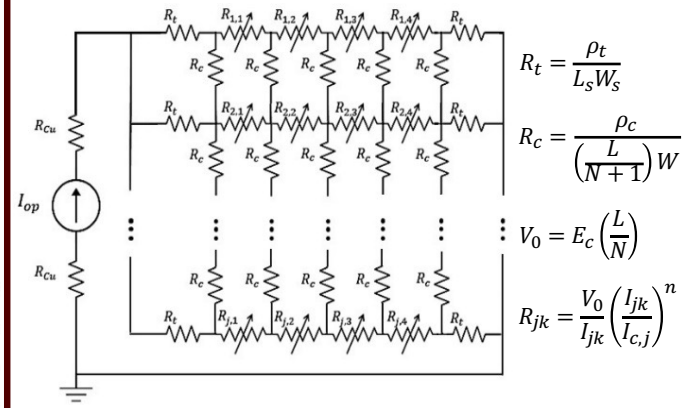
L = Body Length

W = Tape Width

N = 4 divisions (lengthwise)

ρ_t = Terminal Resistivity

ρ_c = Contact Resistivity



$$R_t = \frac{\rho_t}{L_s W_s}$$

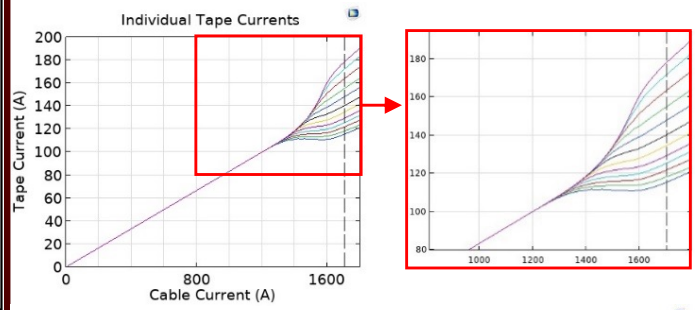
$$R_c = \frac{\rho_c}{\left(\frac{L}{N+1}\right) W}$$

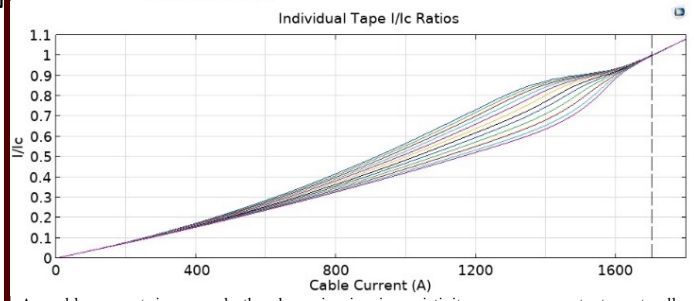
$$V_0 = E_c \left(\frac{L}{N}\right)$$

$$R_{jk} = \frac{V_0}{I_{jk}} \left(\frac{I_{jk}}{I_{c,j}}\right)^n$$

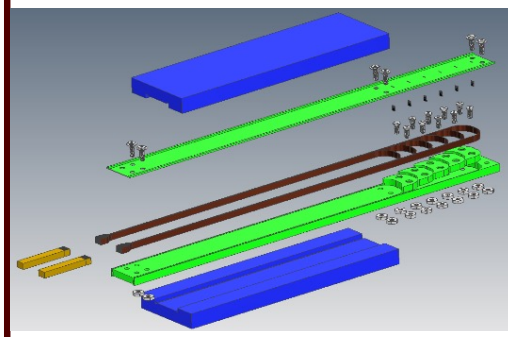
Circuit model (Rogers, IEEE Trans. Appl. Supercond., 2023) for predicting current redistribution in a REBCO tape-stack cable.

Current Redistribution





As cable current is ramped, the dynamic rise in resistivity causes currents to naturally redistribute; tapes with larger I_c carry more current and vice-versa. The circuit model indicates that this effect can be verified by this experiment.



Preliminary CAD model of current array magnet assembly

A Challenge to Tape Manufacturers

We would like to test your conductor in this magnet! REBCO tapes in a non-insulated, non-transposed tape-stack cable offers the benefit of conformal winding strategies and simple cable fabrication. Is there reason to believe your REBCO is well suited for such a current sharing strategy? We are seeking collaborators who can donate 20 m of 6 mm width REBCO tape along with TAPESTAR data and open domain fabrication specifics. Results will be presented at the MT-28 conference in September 2023.

TEXAS A&M UNIVERSITY
Physics & Astronomy

Accelerator Research Lab, TAMU Physics and Astronomy
3380 University Dr. East, College Station, TX, 77845
Corresponding Author: John Rogers - jsr12e@tamu.edu

This research was supported by U.S. Department of Energy SBIR grant to ATC: DDE-SC0021688 – 'Nb3Sn SuperCIC outsert and REBCO conformal insert for an 18 T collider dipole', and U.S. Department of Energy research grant to Texas A&M University: DE-SC0023028 – 'Conformal REBCO windings For high-field dipoles'.