An Electric-Circuit Model on the Inter-Tape Contact Resistance and Current Sharing for REBCO Cable and Magnet Applications

Aurora Cecilia Araujo Martinez[1,2], Qing Ji[2], Soren Prestemon[2], Xiaorong Wang[2], Geofrey Humberto Israel Maury Cuna[1]
[1] Universidad de Guanajuato; [2] Lawrence Berkeley National Laboratory
Email: araujoma2012@licifug.ugto.mx

Introduction

REBCO wire has multiple potential applications:
- CORC® wires for high-field accelerator magnets
- TSTC for fusion and power transmission
- REBCO pancake coils and layer wound coils
  - NHMFL 32 T user magnet
  - NMR and MRI

Challenges
- Difficult to protect REBCO magnets against quench
- Unavoidable critical current and n-value variations along the tape length

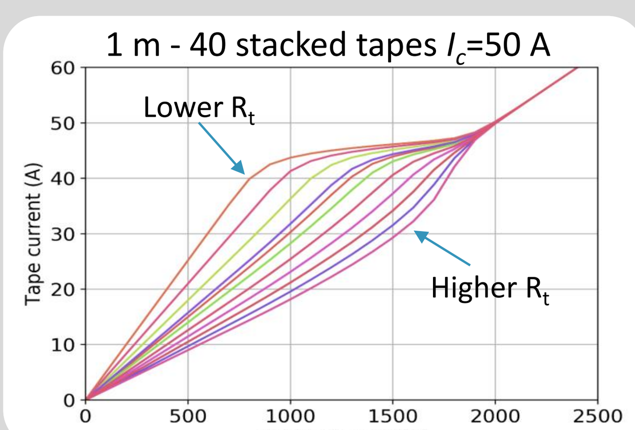
Contact resistance R_c in REBCO tapes plays a key role
- Low contact resistance allows current sharing
- High contact resistance causes excessive generation of Eddy currents

Driving questions

- Can we use a simple circuit model to provide important insight on the impact of R_c in REBCO cables?
- What is the optimal R_c for REBCO cables?
- What is the impact of having I_c and n-value variations on the performance of different REBCO cable configurations?

Validation of the model

We reproduced the results published by Takayasu *et al.* for a TSTC in self field at 77 K.



References

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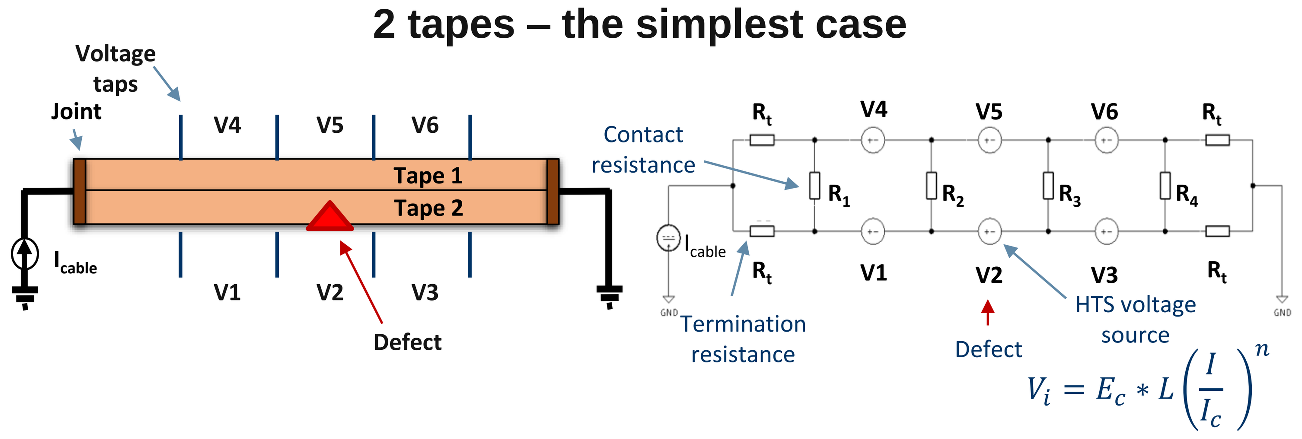
Model

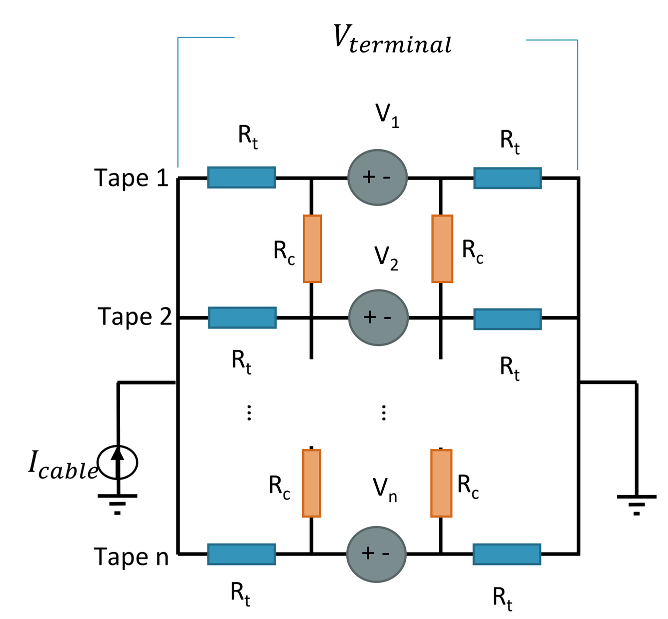
Electric-circuit model based on Ngspice to study the impact of contact resistance on stacked-tape cable.

2 tapes – the simplest case

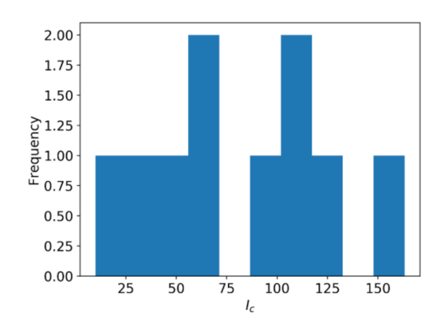


Model for Monte Carlo simulations to study the impact variations in I_c and n-value on the cable performance

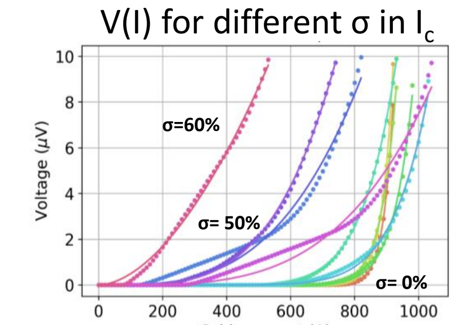
n-stacked tape cable



Example: 10 stacked-tapes
I_c distribution for σ = 50%



V(I) for different σ in I_c

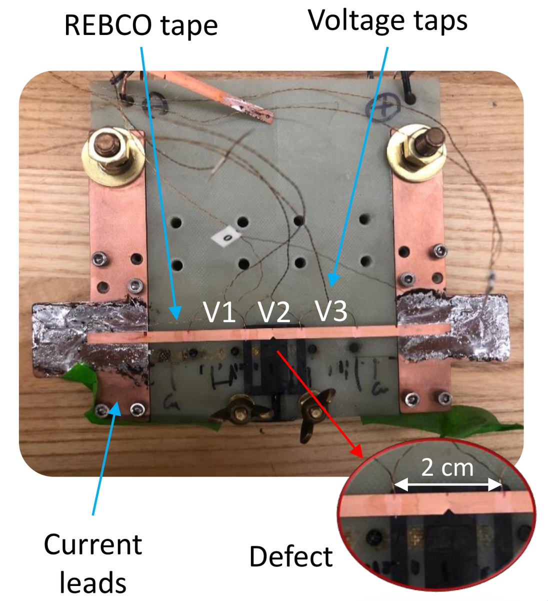


Measurements in 2-stacked tapes

Impact of R_c in a 2-tape cable with local defect:
- Insulation with Kapton tape for high R_c
- Solder $Pb_{40}Sn_{60}$ for low R_c

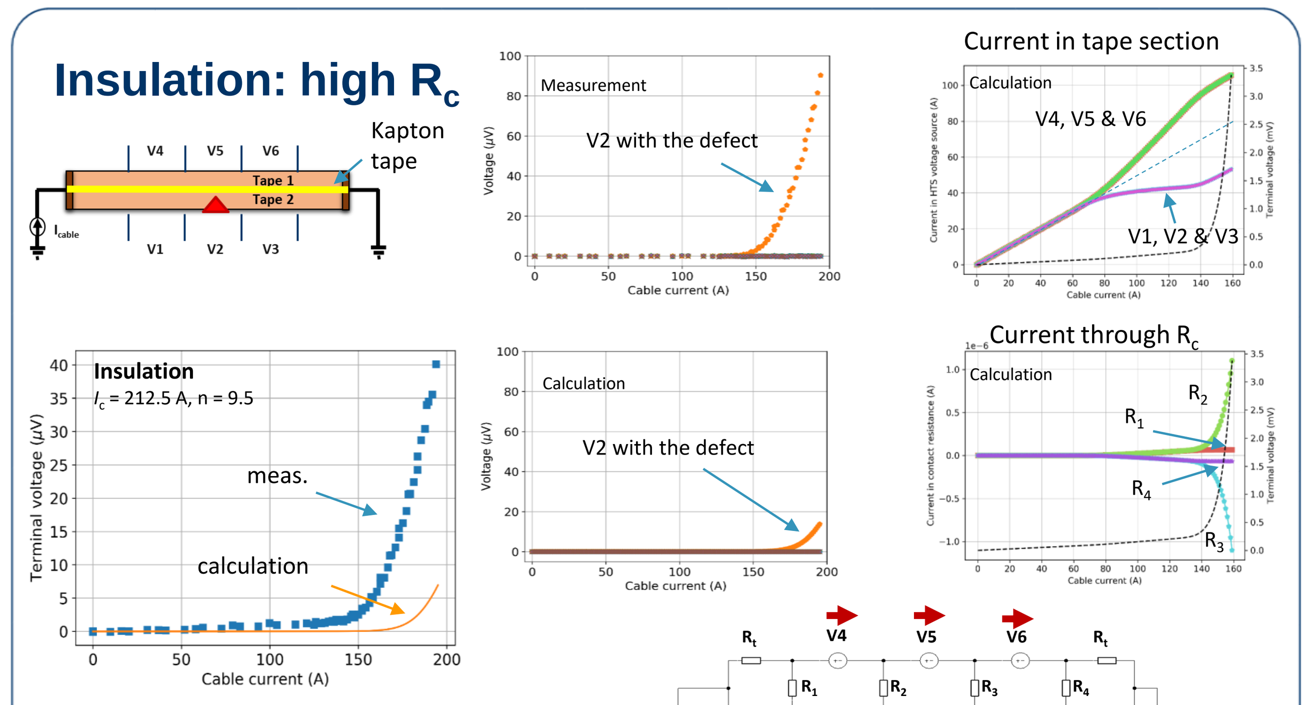
HTS section	I_c at 77 K, s.f. (A)		n	
	Before	After	Before	After
V1	132.3	*	30.5	*
V2	89.4	86.7	24.2	24.4
V3	133.1	*	31.0	*
V4	133.1	130.4	28.9	28.8
V5	130.7	129.9	30.7	29.9
V6	131.8	129.2	29.7	28.3

* Values that could not be measured after unsolder



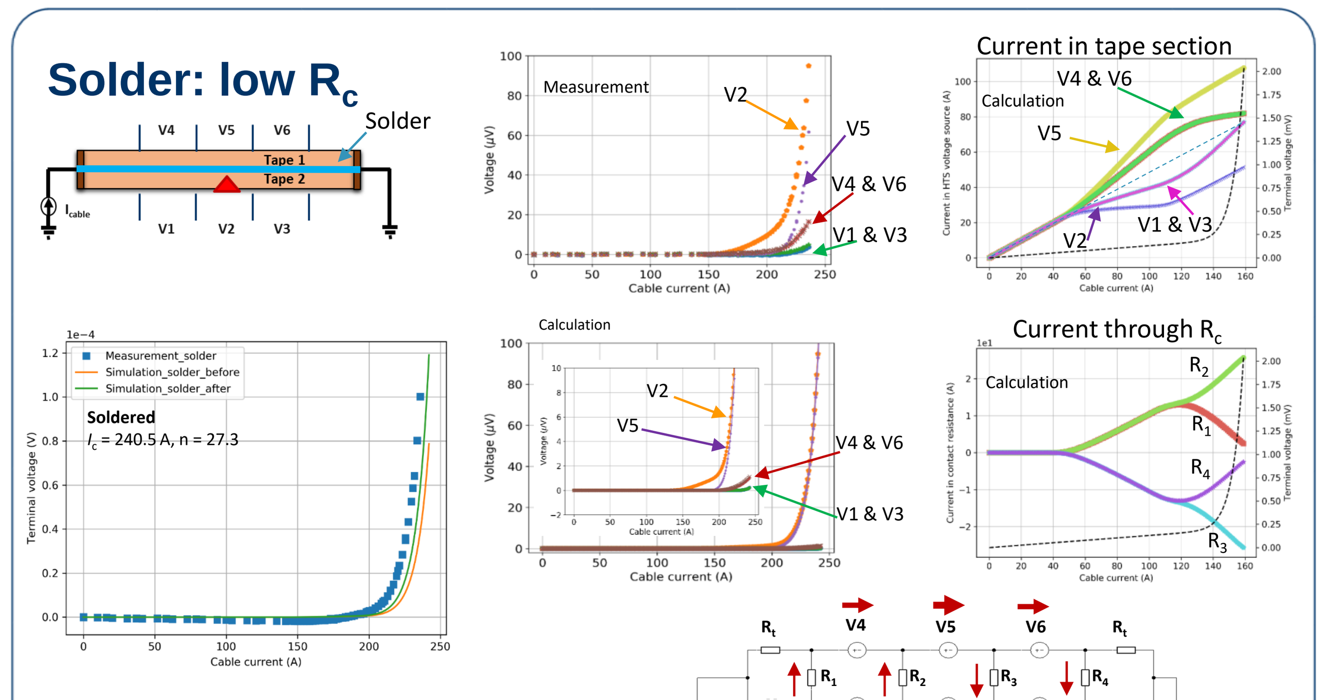
Results

Insulation: high R_c



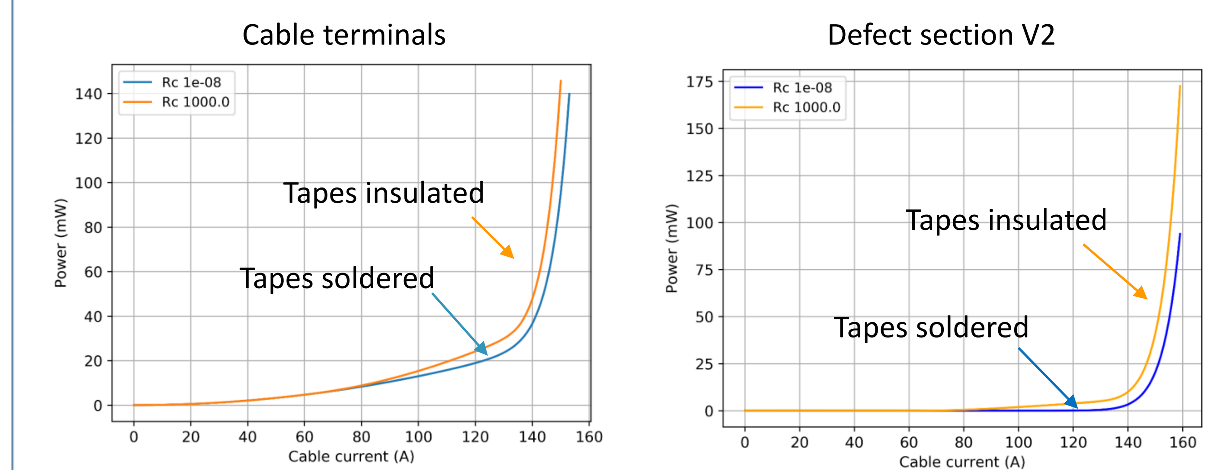
R_c = 1000 Ω

Solder: low R_c



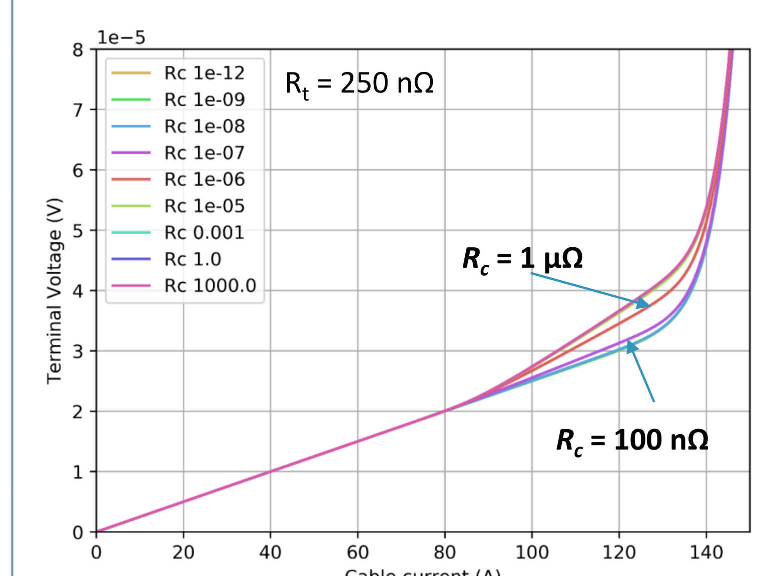
R_c = 46 nΩ

Impact of R_c on heat generation



*tape 1 I_c= 95.13 A, n=32.15; tape 2 I_c=40 A, n = 16

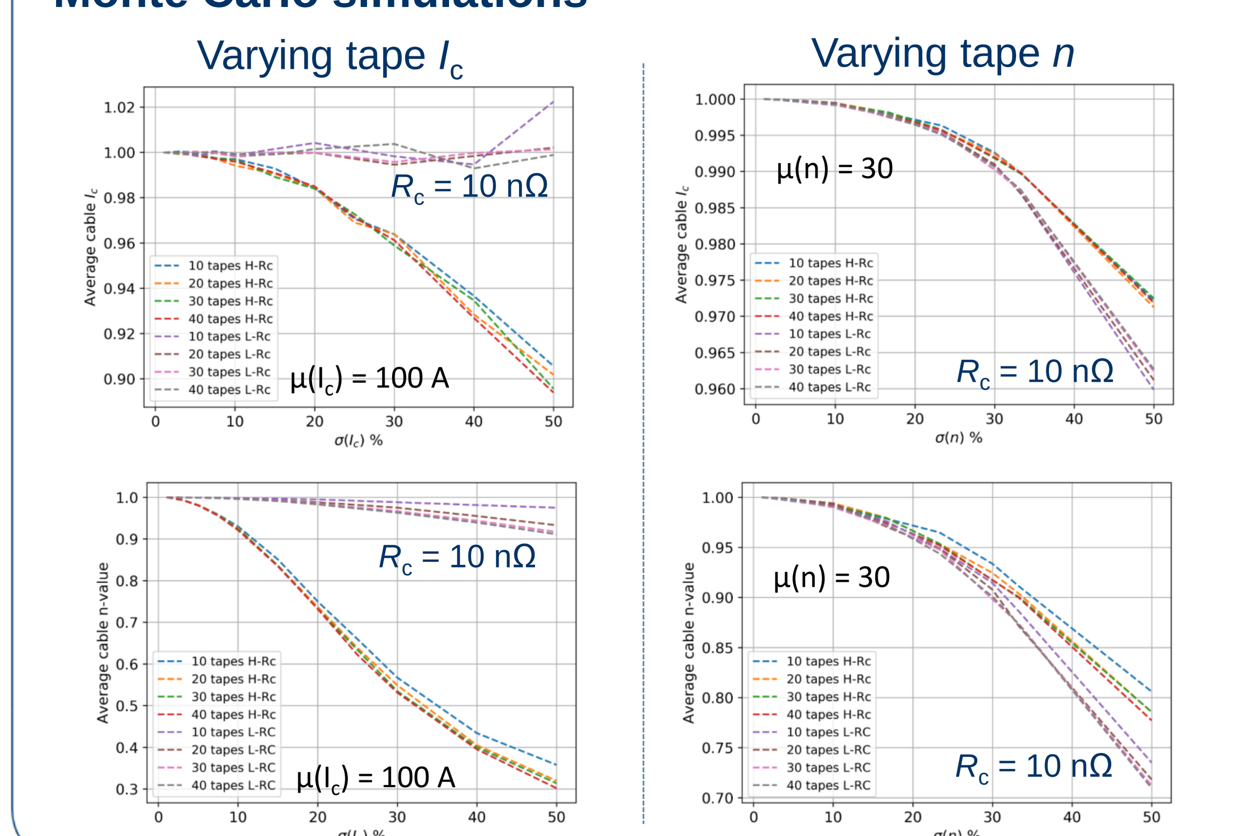
Optimal R_c with respect to terminal resistance



R_t	Good contact (Ω)
25 µΩ	≤ 10 µ
250 nΩ	≤ 100 n
2.5 nΩ	≤ 1 n

*tape 1= 100 A; tape 2=50 A. n = 30

Monte Carlo simulations



Conclusions

- We developed a simple circuit model to help understand the impact of R_c and current sharing for REBCO cables.
- The model reproduces the published results on stacked-tape cable.
- Qualitative agreement with measurements in 2-tape stack cable soldered and with insulation was showed.
- Low contact resistance allows current to bypass defects and to reduce the power generation during the cable transition.
- Reducing R_c, will make the cable performance (I_c and n-value) less affected by the variation of I_c in the tapes.

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