A method to simulate SIC-SFCL in 3D FEM coupled to electrical circuits

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Summary

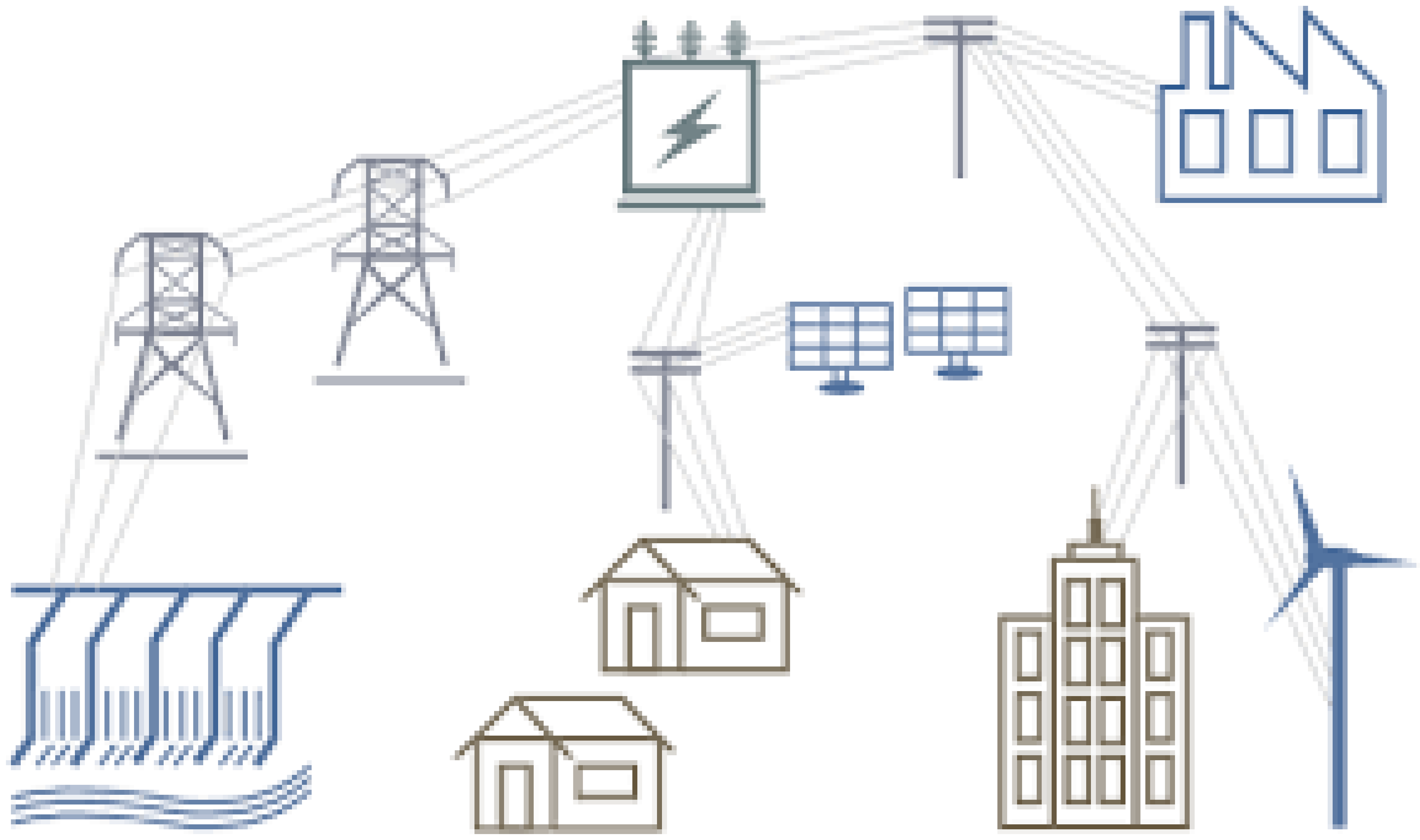
1. Introduction
2. Methodology
3. Results
4. Conclusion

Introduction

Contextualization:

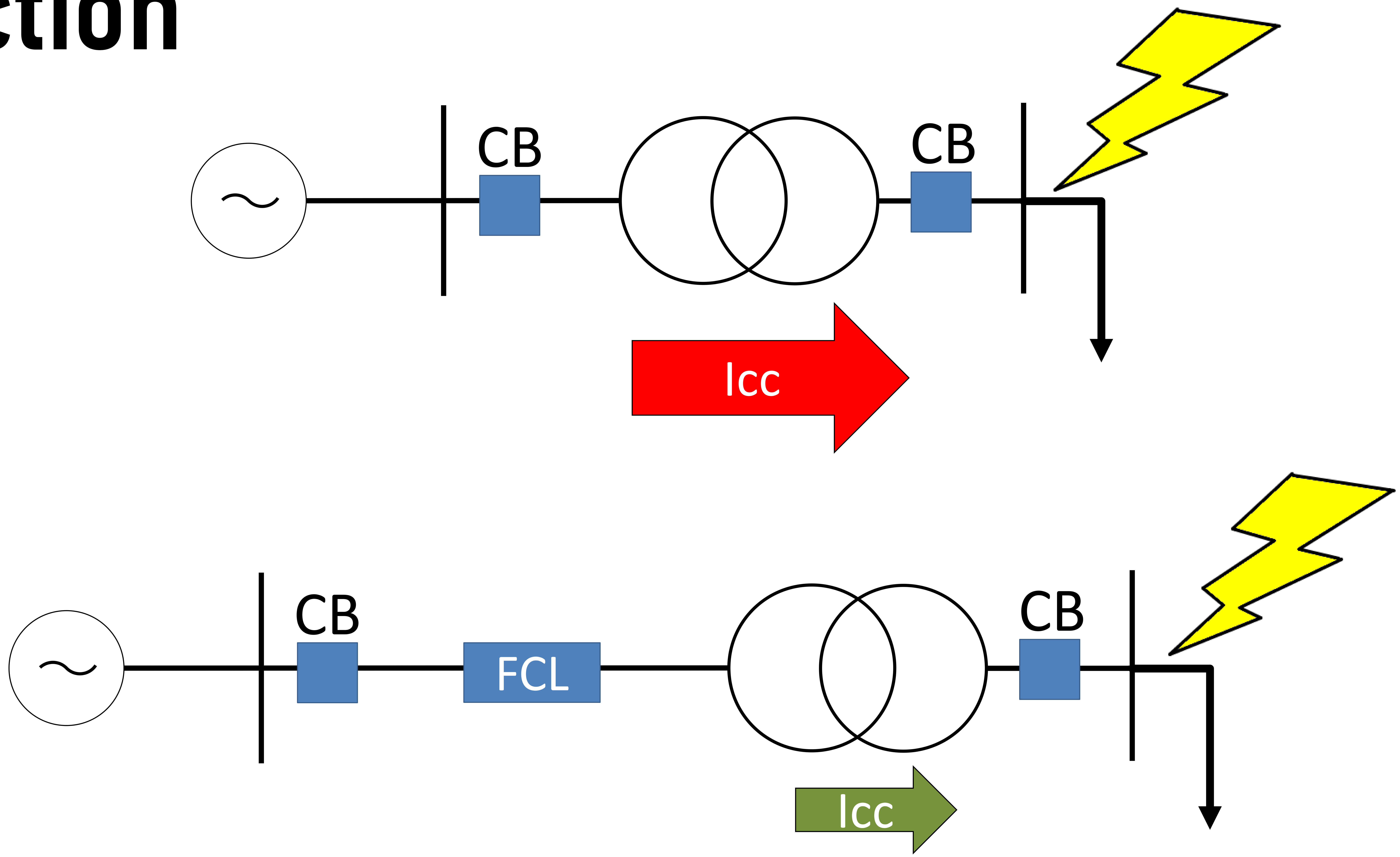
•Load increasing

•Distributed Generation Increasing



Introduction

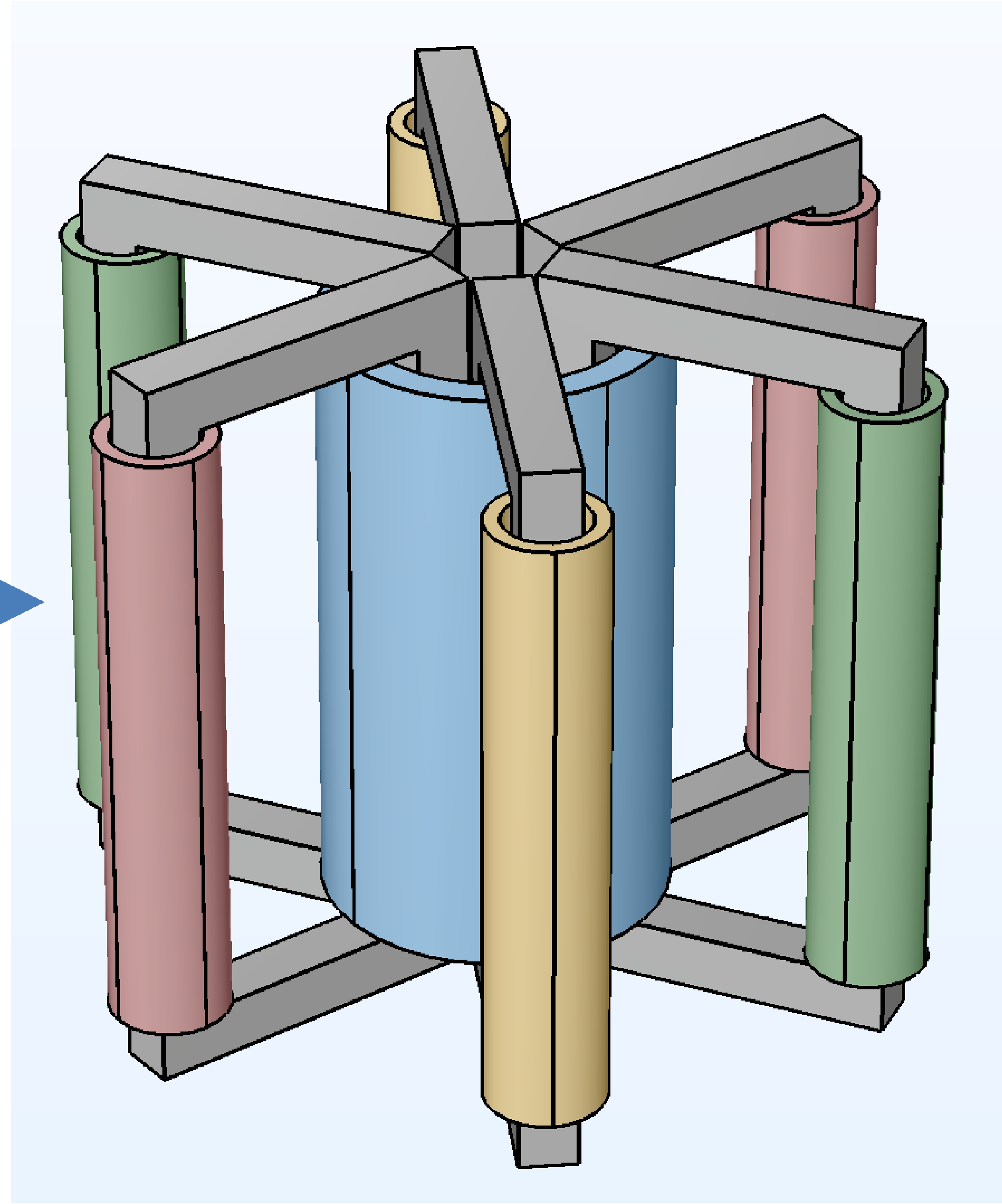
Motivations:



Introduction

Topologies:

- SFCL
  - Non-quench Type
    - Saturated Iron Core
    - Resonance
    - Bridge
    - Transformer with HTS coil
  - Quench Type
    - Magnetic shielded iron core
    - Resistive
    - Hybrid
    - SFCL transformer
    - Flux-look
    - Transformer SFCL
    - Coreless/air core inductive



Introduction

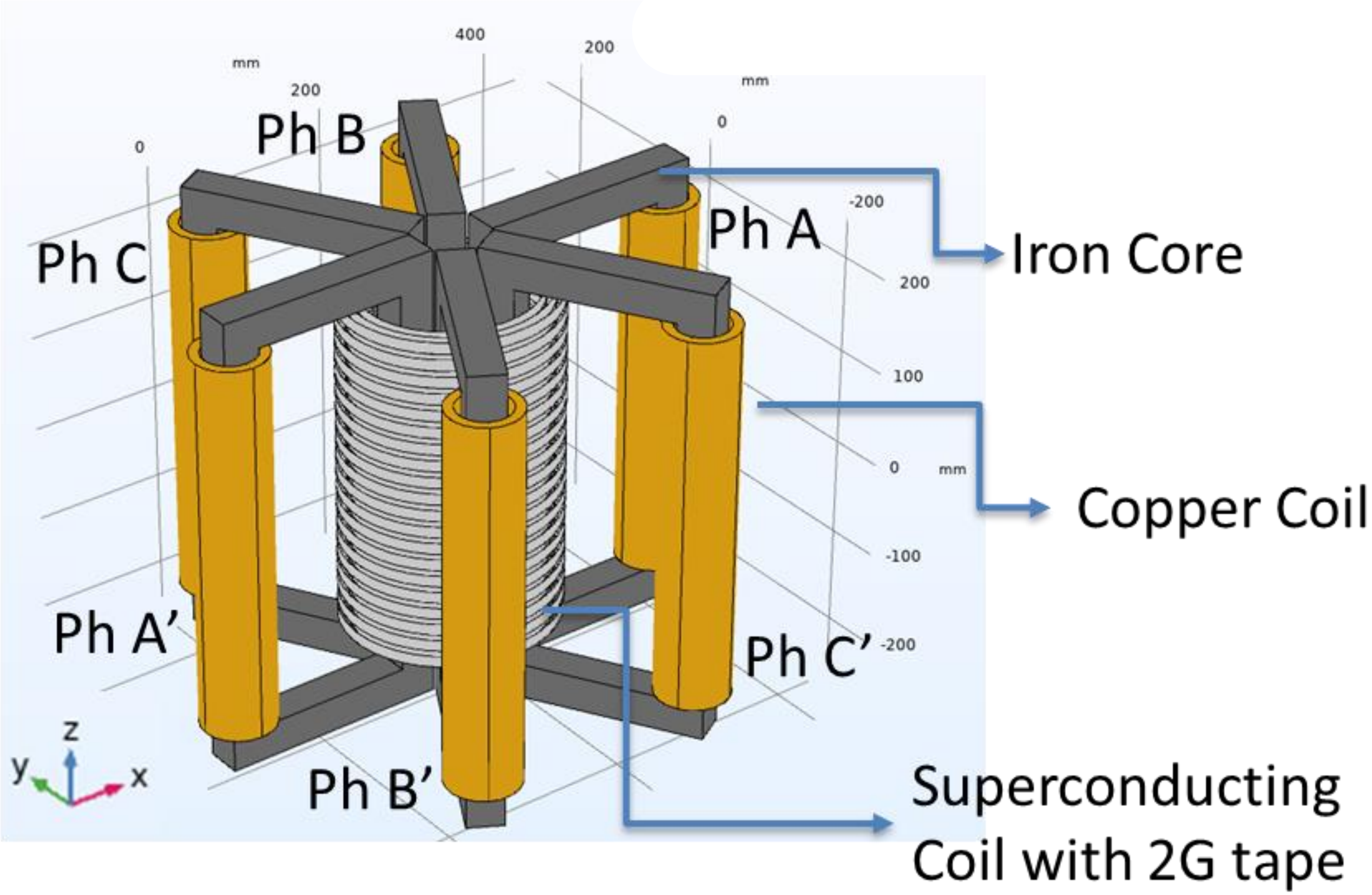
Fundamental Principals:

- Magnetic Flux Density due to DC current
- Magnetic Flux Density due to AC current

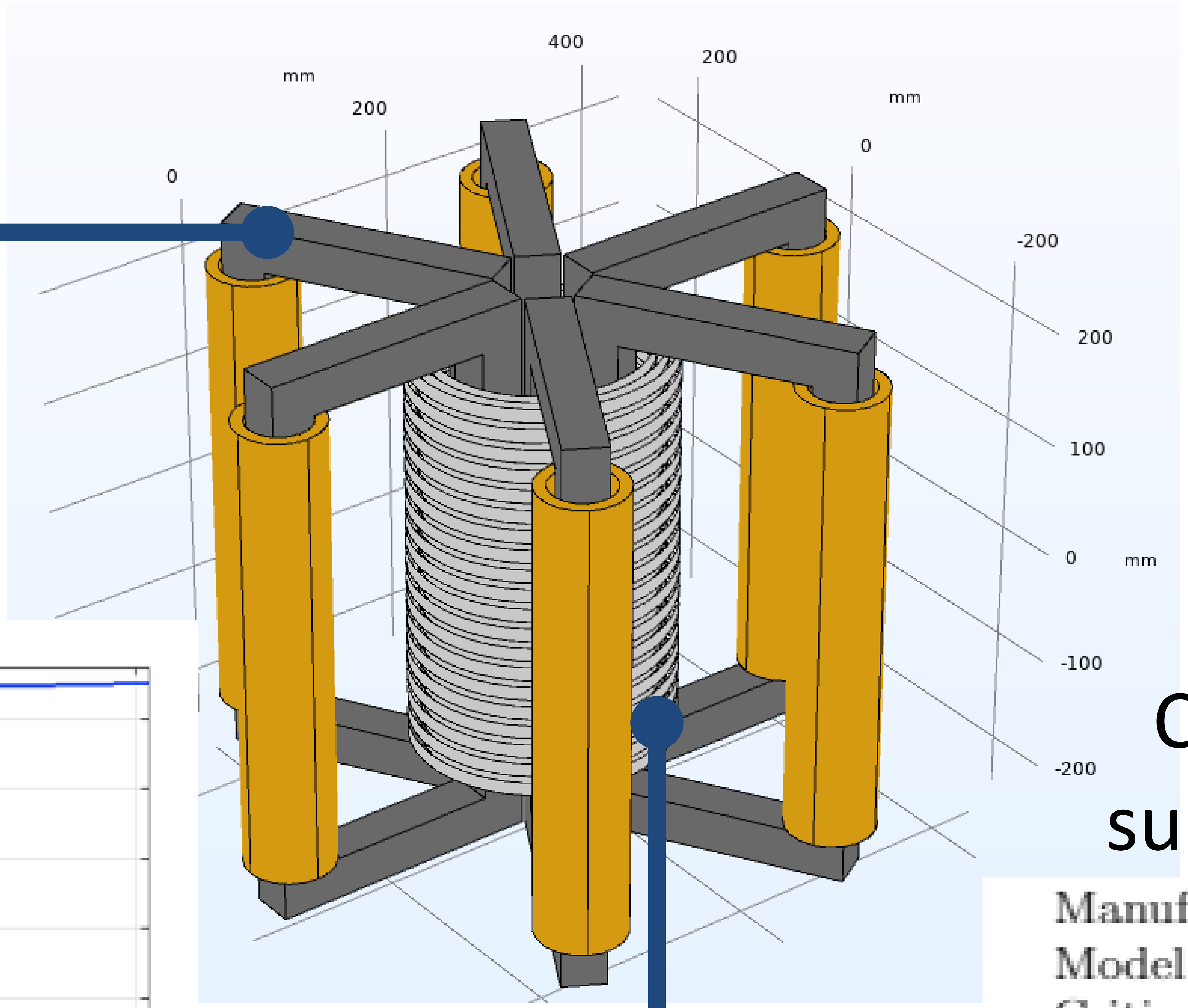
Methodology

Simulation Model

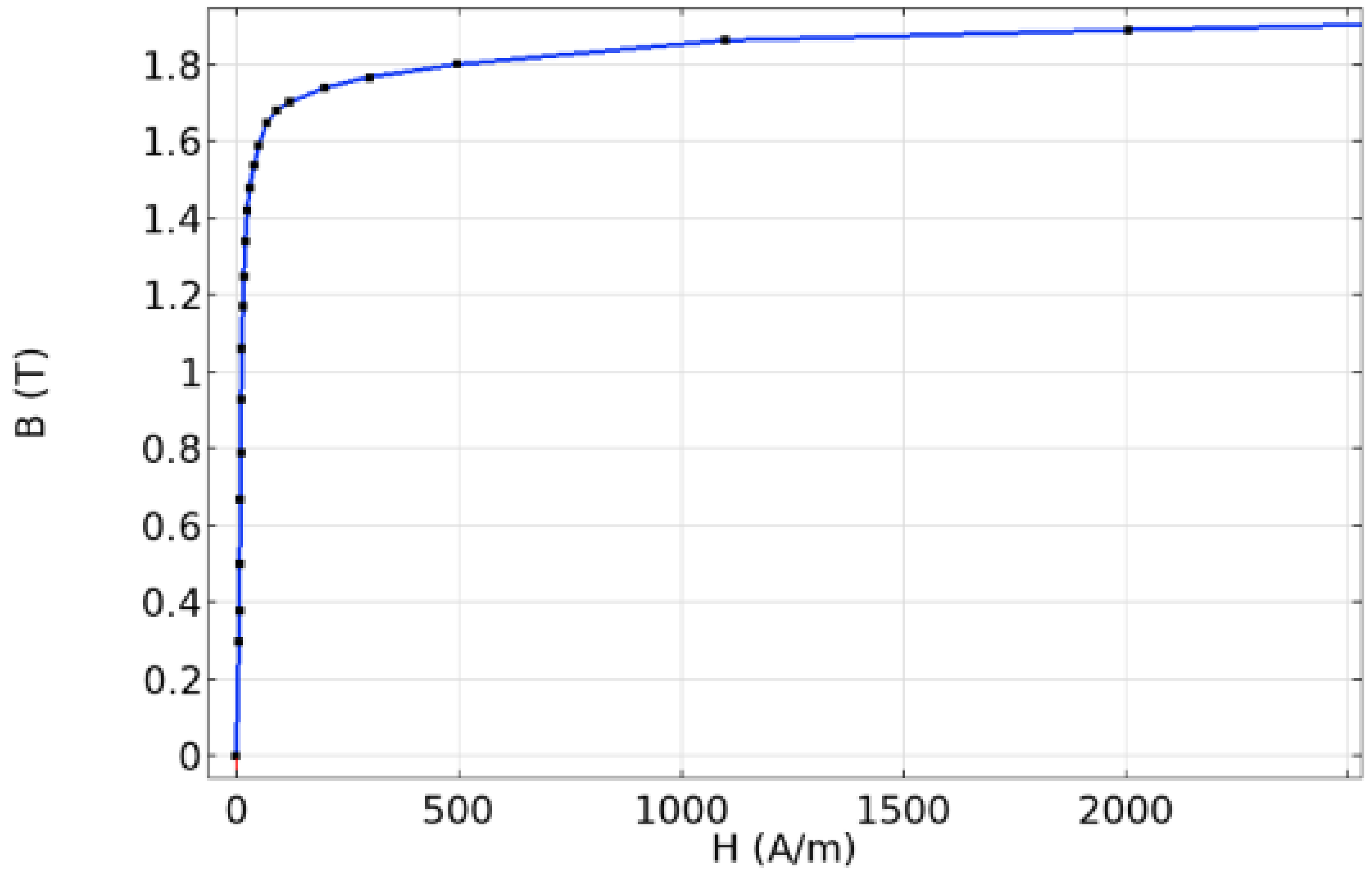
3D SIC-SFCL Model



Methodology



Characterization of the ferromagnetic material



Characterization of the superconducting material

Manufacturer	AMSC
Model	8502
Critical Current @ 77K(I_c[A])	389.75
Width (W_d[mm])	12
Superconductor thickness (t_{sup}[μm])	1
Tape thickness (t_{tape}[μm])	200
Anisotropy factor (k) [a]	0.186
B_0[T] [a]	0.426
α [a]	0.7
Transiton index @ 77K(n)	29

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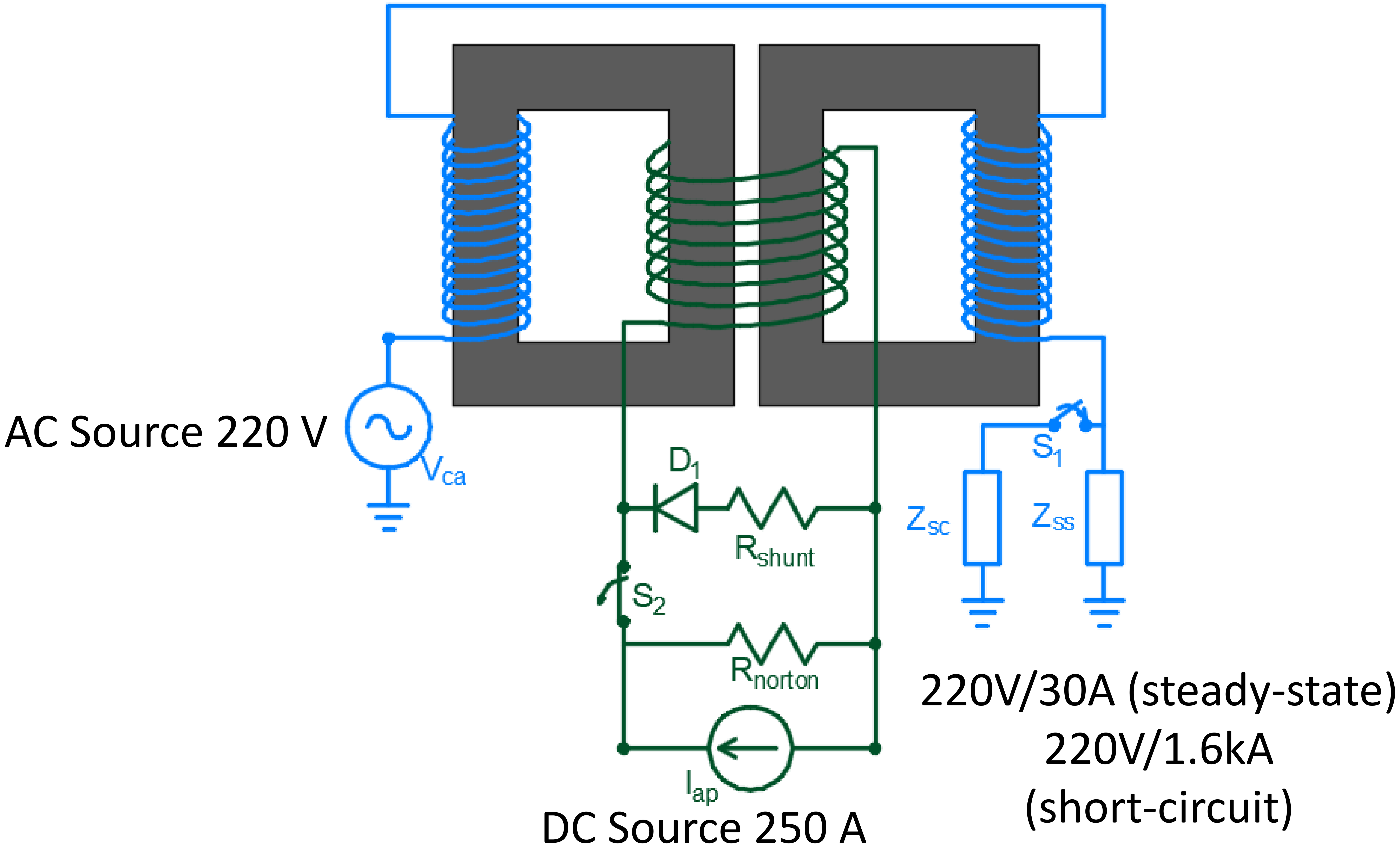
Methodology



Methodology

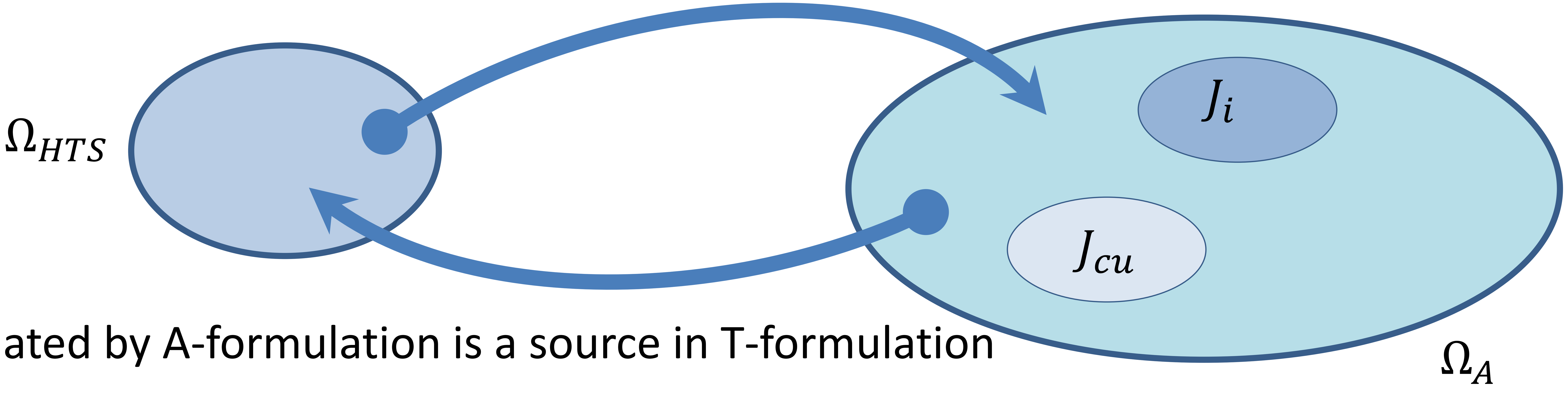
T-Formulation

$$\nabla \times (\rho \nabla \times \boldsymbol{T}) = -\frac{\partial \boldsymbol{B}}{\partial t}$$

A-Formulation

$$\nabla \times \left(\frac{1}{\mu} \nabla \times \boldsymbol{A}\right) = \boldsymbol{J}_{\boldsymbol{HTS}} + \boldsymbol{J}_{\boldsymbol{cu}} + \boldsymbol{J}_{\boldsymbol{i}}$$

$\boldsymbol{J}_{\boldsymbol{HTS}}$ calculated by T-formulation is a source in A-formulation



$\boldsymbol{B}$ calculated by A-formulation is a source in T-formulation

PAPER

An efficient 3D finite element method model based on the *T–A* formulation for superconducting coated conductors

Huiming Zhang[1,1], Min Zhang[1] and Weijia Yuan[1]

Published 13 December 2016 • © 2016 IOP Publishing Ltd

Superconductor Science and Technology, Volume 30, Number 2

Focus on Numerical Modelling of High Temperature Superconductors

Citation Huiming Zhang *et al* 2017 *Supercond. Sci. Technol.* **30** 024005

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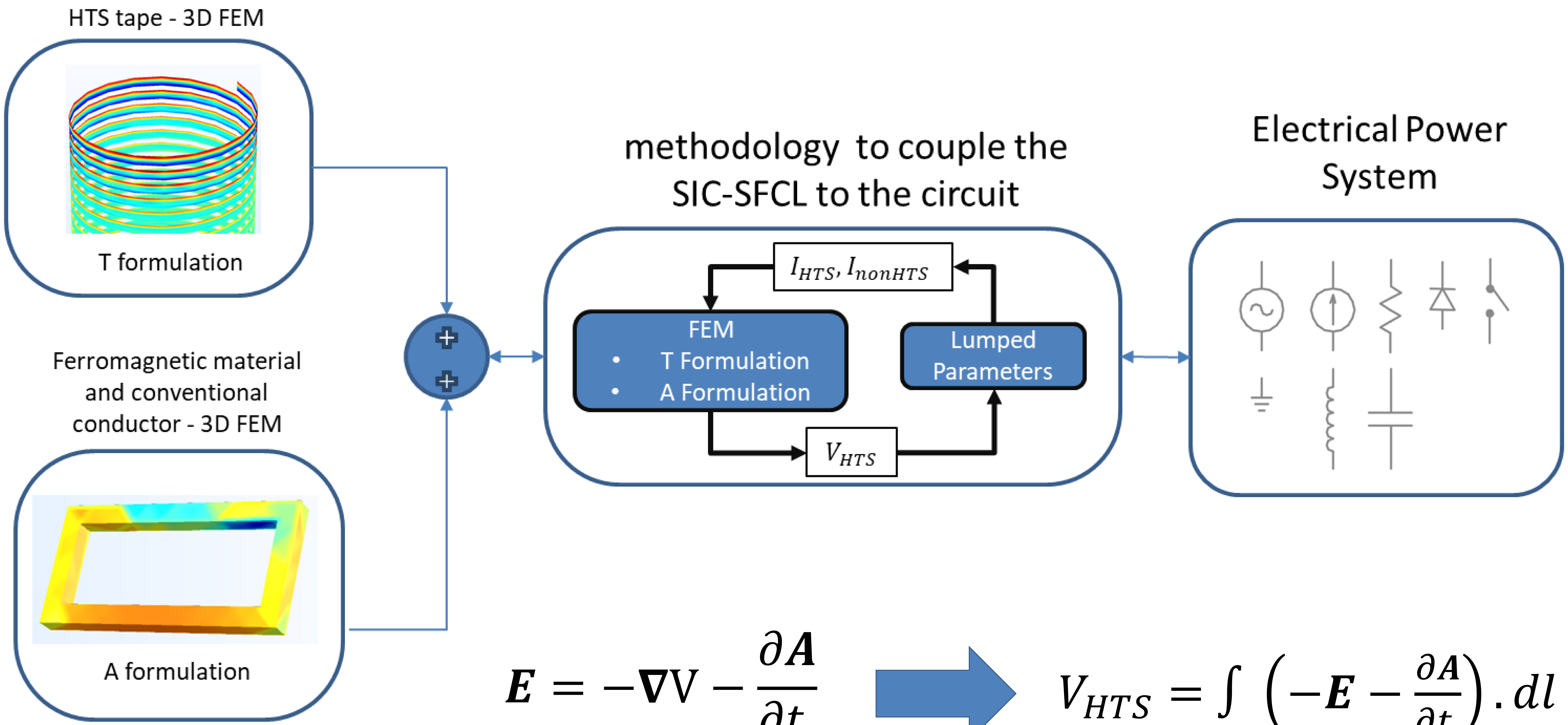
Methodology

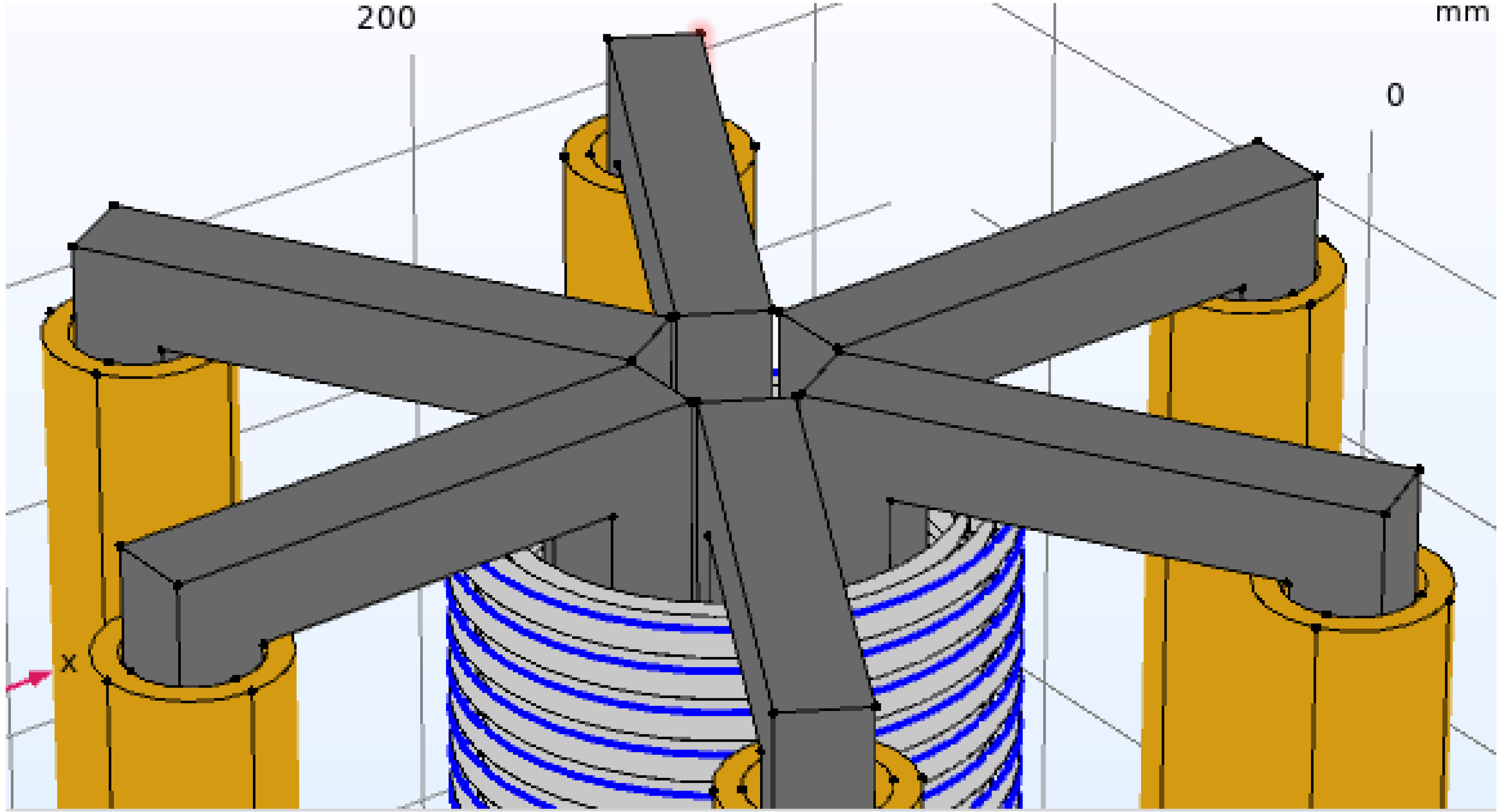


$$\boldsymbol{E} = -\nabla \mathrm{V} - \frac{\partial \boldsymbol{A}}{\partial t} \quad \Rightarrow \quad V_{HTS} = \int \left(-\boldsymbol{E} - \frac{\partial \boldsymbol{A}}{\partial t}\right) . dl$$

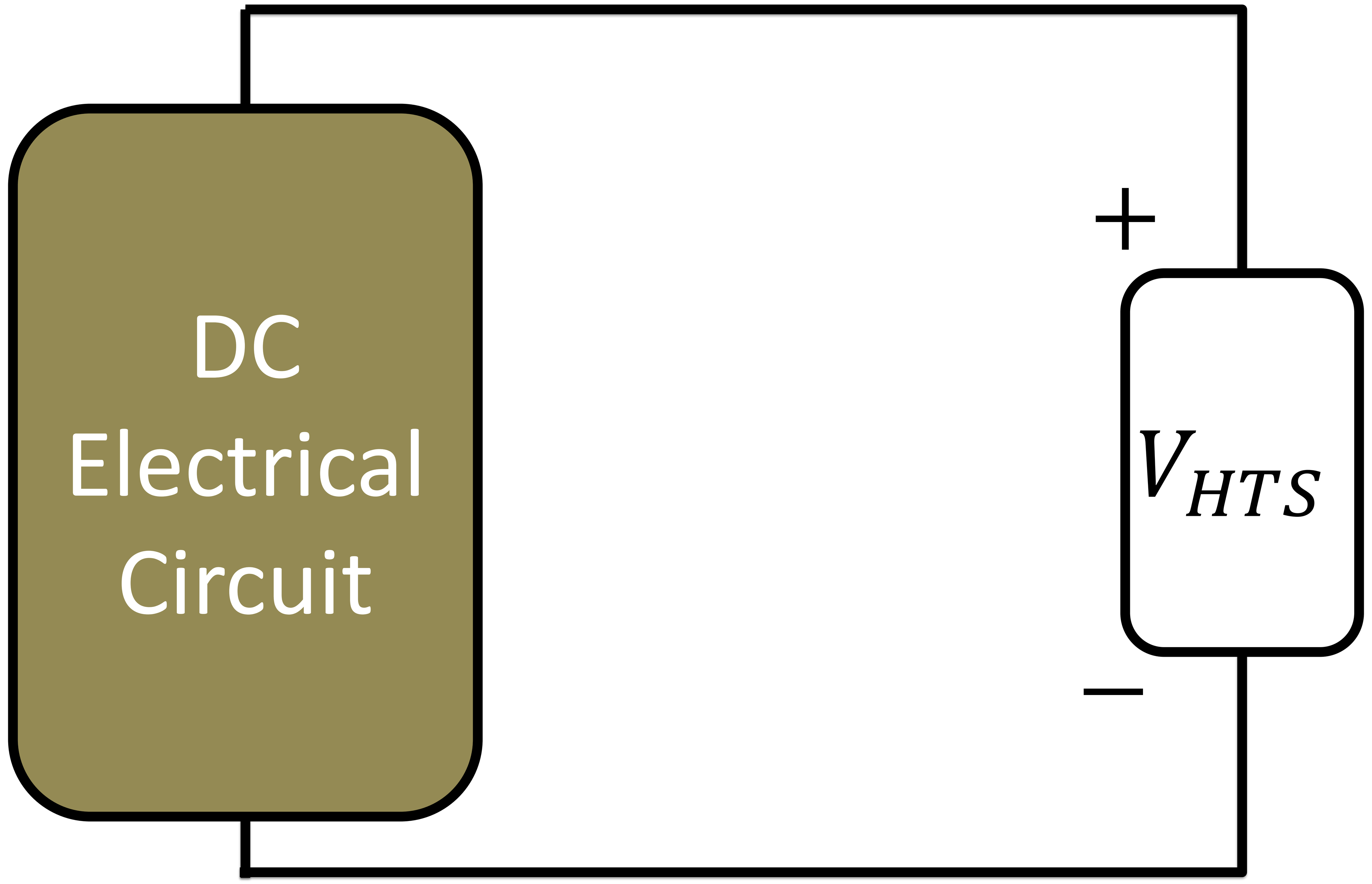
Methodology

$$V_{HTS} = \int \left(-\boldsymbol{E} - \frac{\partial A}{\partial t}\right).\boldsymbol{dl}$$

$$\frac{\partial}{\partial t}\boldsymbol{A}.\boldsymbol{dl} = \frac{\partial}{\partial t}(A_x.a_x dx + A_y.a_y dy + A_z.a_z dz)$$



$$\boldsymbol{E}.\boldsymbol{dl} = E_x.a_x dx + E_y.a_y dy + E_z.a_z dz$$



Methodology

Electrical Schematic of the simulated SIC-SFCL:

T formulation $(T_1 - T_3).\, d_{HTS} = I_{HTS}$

A formulation $n \times (\boldsymbol{H_1} - \boldsymbol{H_2}) = \boldsymbol{J_{HTS}}.\, d_{HTS}$

Results

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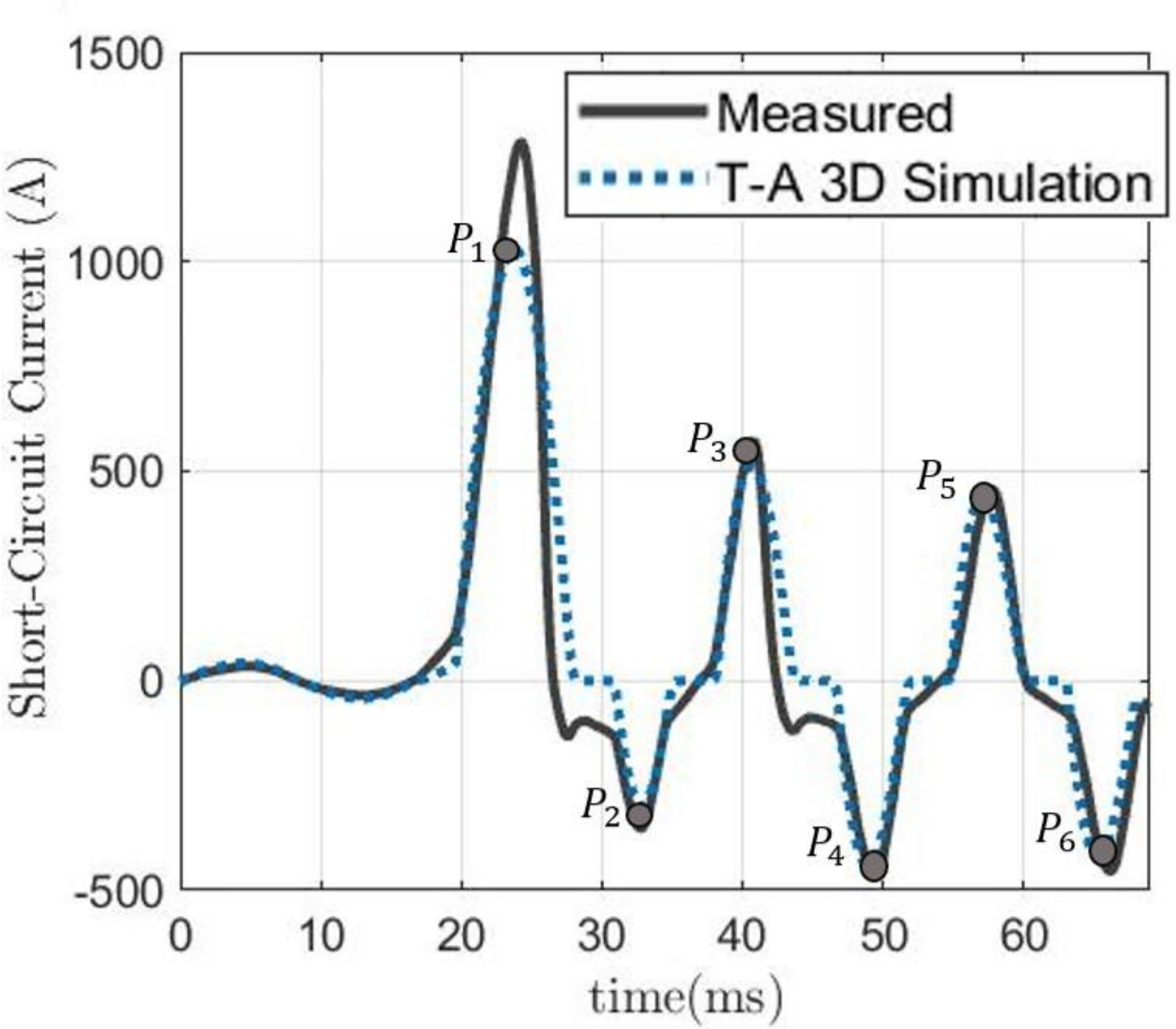
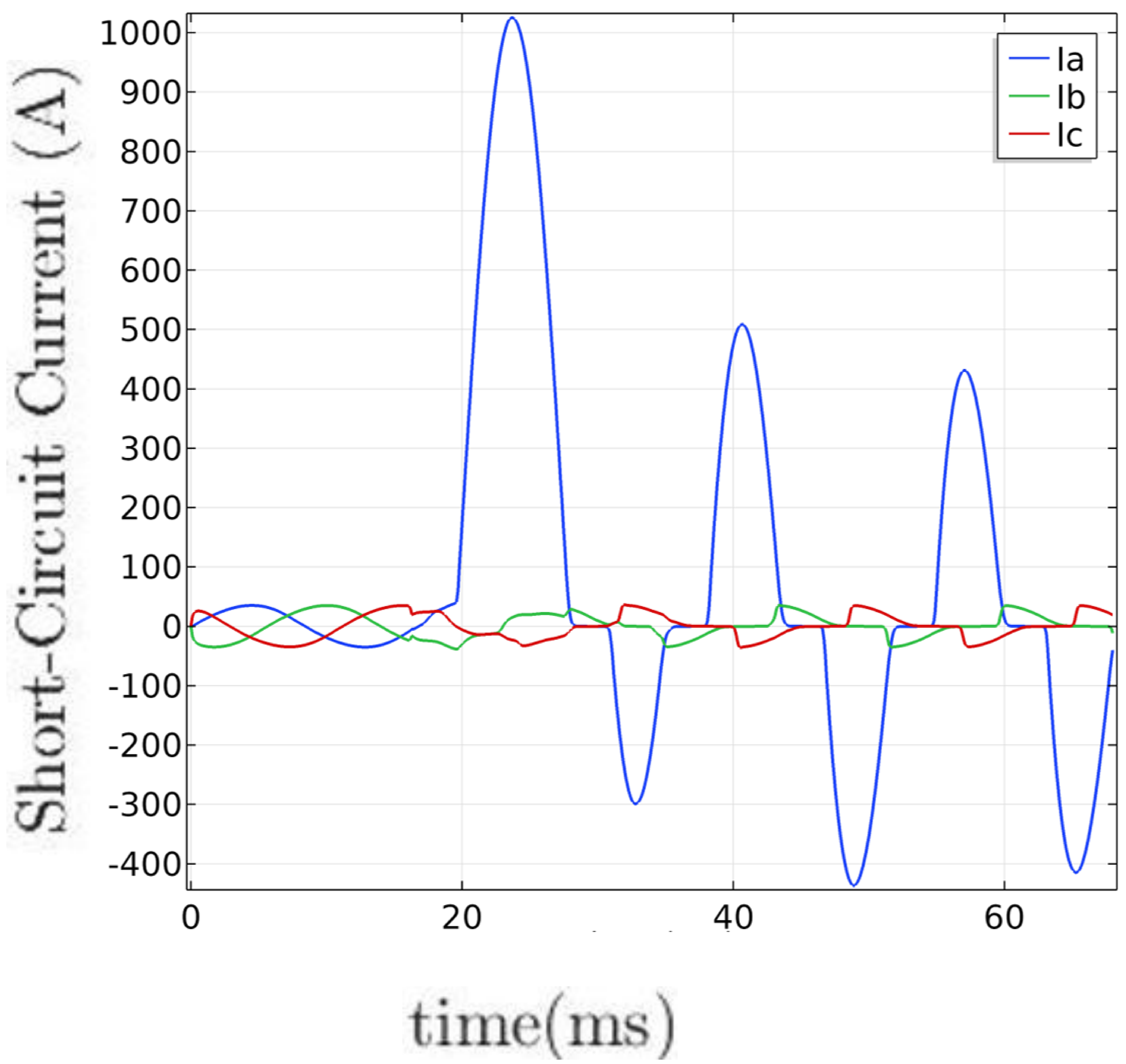
Results



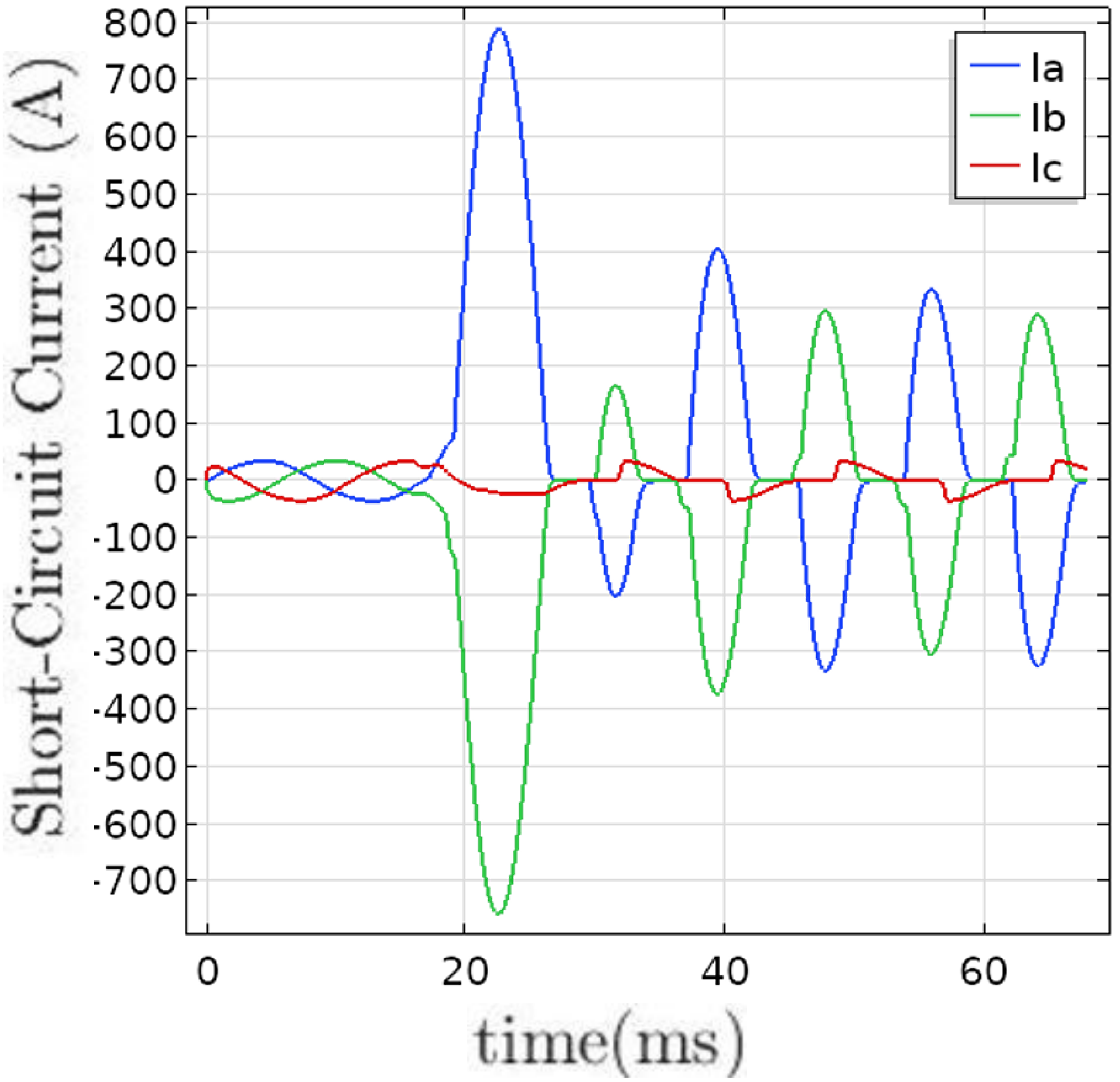
Measured
T-A 3D Simulation
Short-Circuit Current (A)
time(ms)
1500
1000
500
0
-500
0
10
20
30
40
50
60
P_1
P_2
P_3
P_4
P_5
P_6

Results

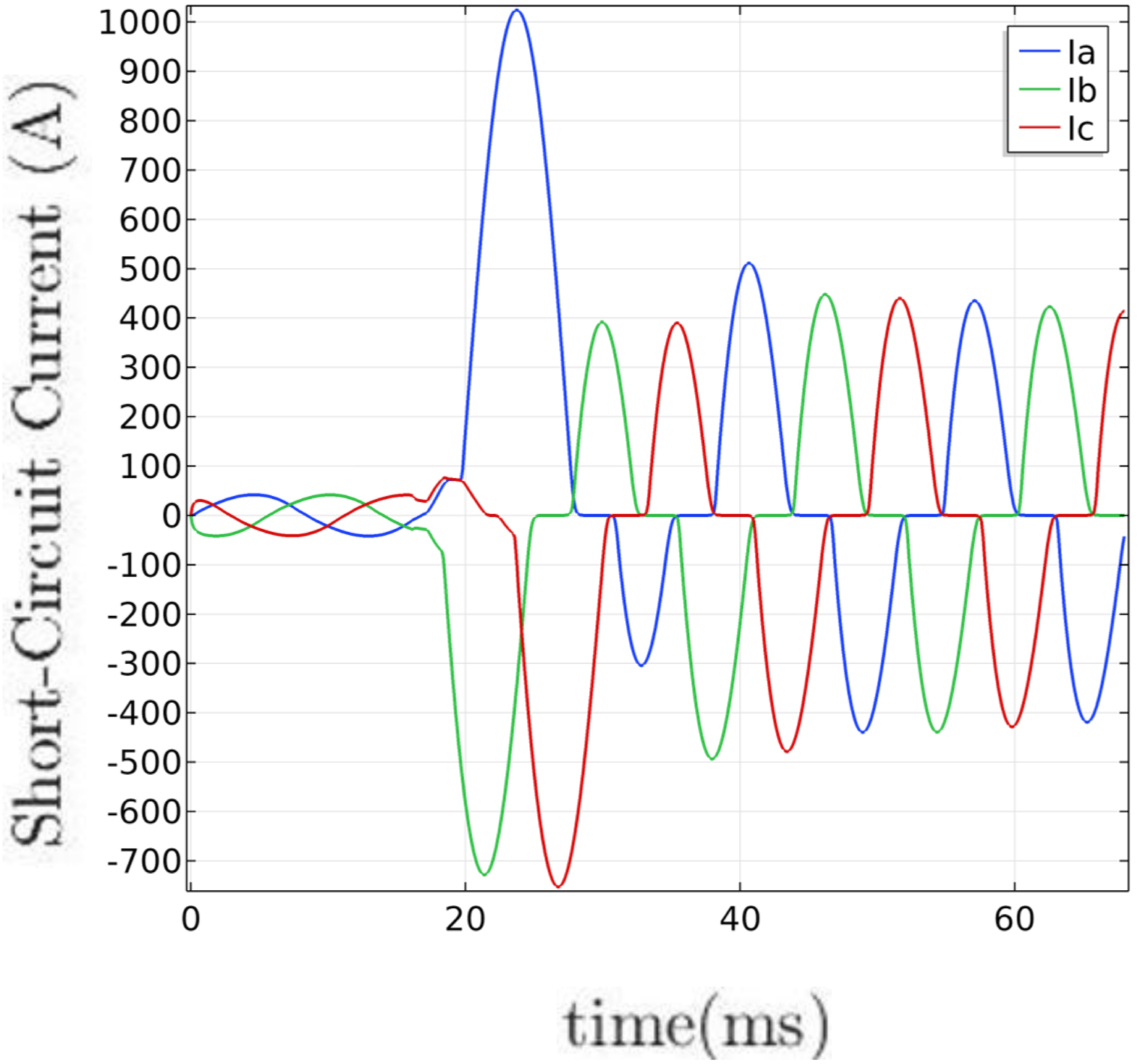
1ϕ



2ϕ



3ϕ



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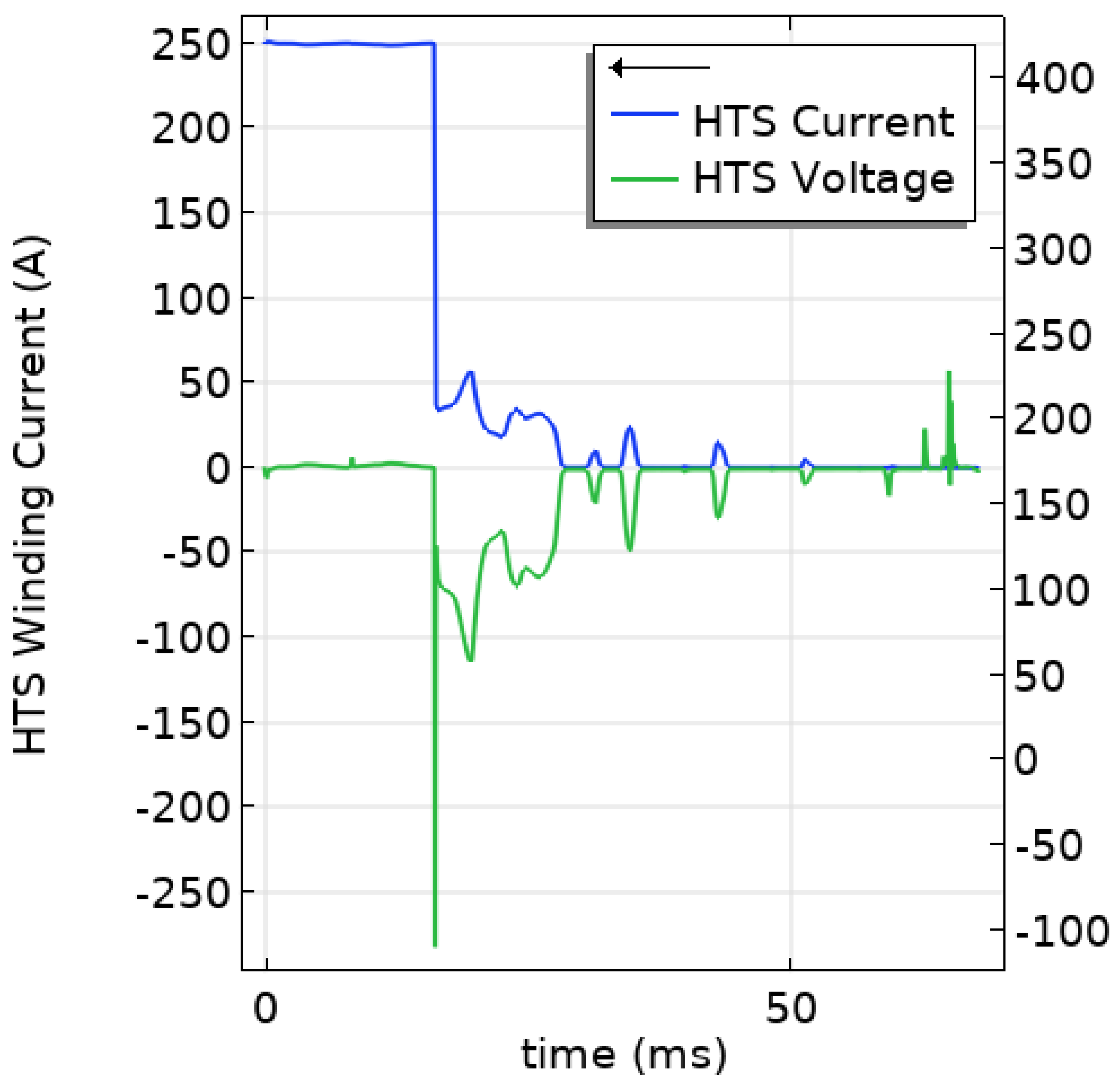
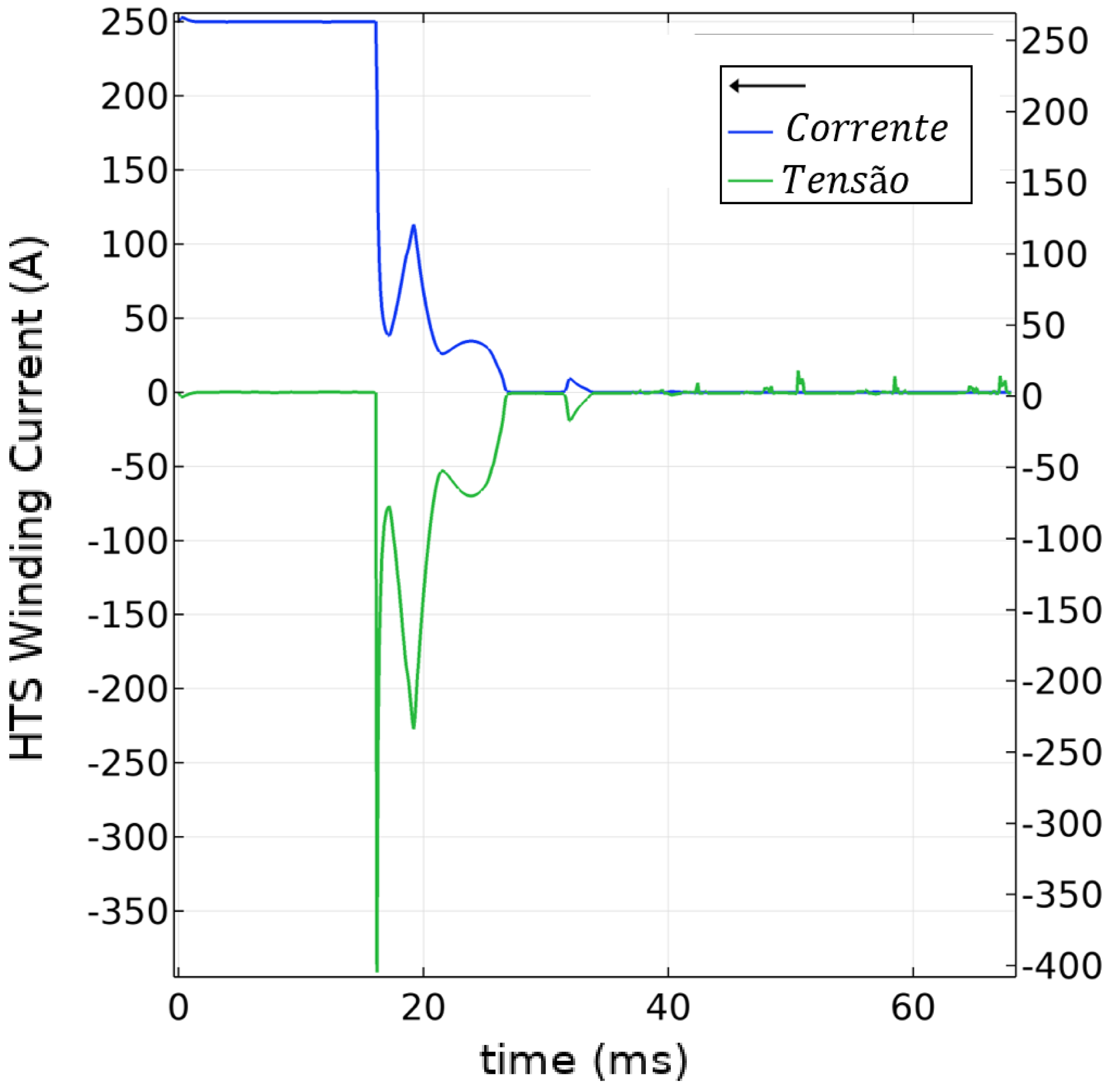
Results

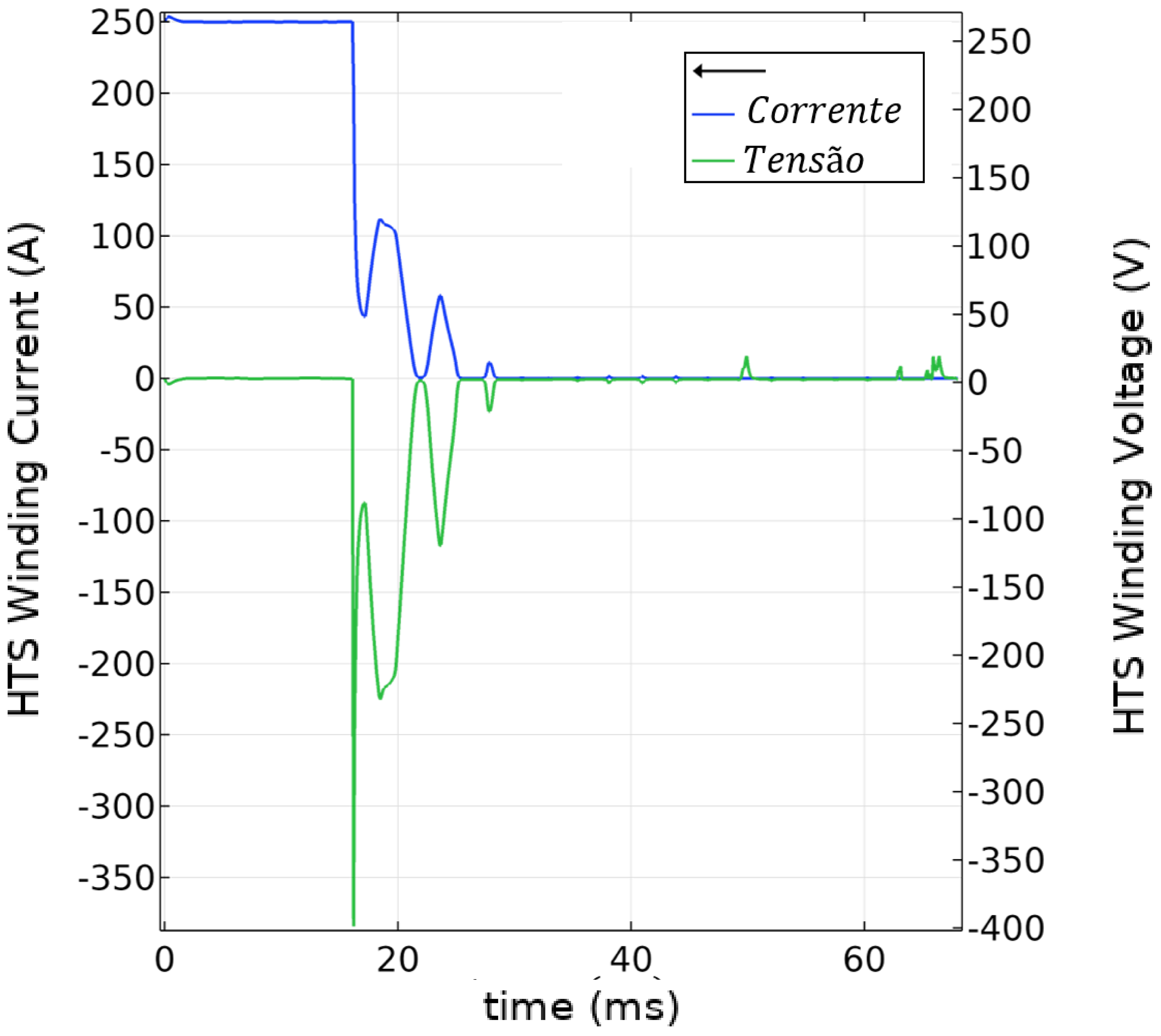
1ϕ



2ϕ



3ϕ



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Conclusion

1. The SIC-SFCL was simulated and validated by the experimental tests of the SIC-FCL.
2. Impacts analysis of different short-circuits was performed in order to predict the fault with the highest impact over the DC coil.
3. The highest impact over the DC coil was found in the phase-to-phase short-circuit.
4. Regardless of the kind of short-circuit, all phases are impacted.

Thank you so much

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