Electromagnetic Characteristics of an Aluminum-stabilized Stacked HTS Tape Cable No-Insulation Coil

Qingyuan Li[1,2], Yatian Pei[2], Menglin Wang[2], Yuanlong Ding[1,2], Qingjin Xu[2], Wei Pi[1], and Feipeng Ning[2]

1) The State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources and the Key Laboratory of HV and EMC Beijing, North China Electric Power University, Beijing, 102206, China

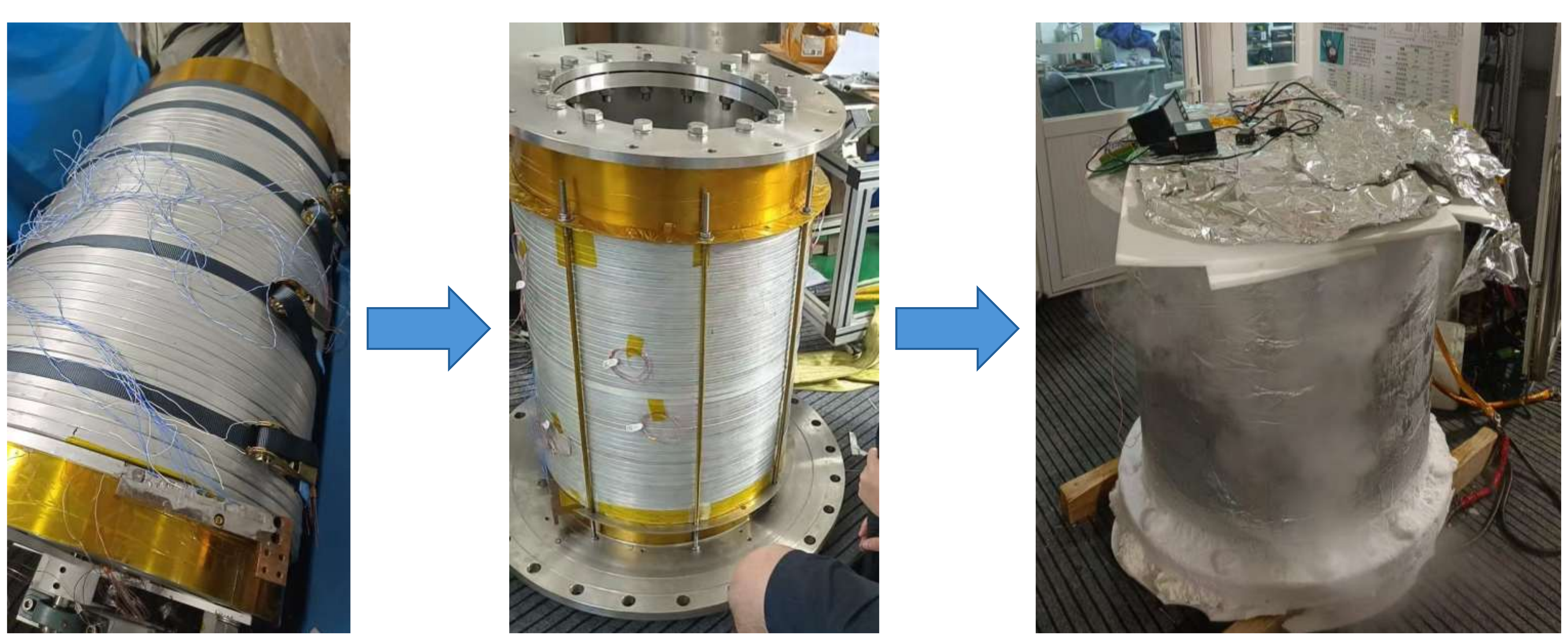
2) Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

ABSTRACT

This paper presents an Aluminum-stabilized Stacked HTS Tape Cable (ASTC) solenoid coil for the Circular Electron Positron Collider (CEPC) detector. Its electromagnetic properties are systematically studied through experiments and simulations. Tests at current ramp rates of 0.2, 1, and 5A/s analyse voltage response and magnetic field delay. Results show the aluminum stabilizer significantly suppresses field delay, contrasting with no-insulation coils and enabling precise electromagnetic control. Finite element modeling examines how inter-turn contact resistance affects the time constant, refining the ASTC coil theoretical framework. This study provides experimental and theoretical insights into the electromagnetic response of ASTC solenoid coils, supporting the design and application of high-temperature superconducting magnets for the CEPC detector.

EXPERIMENTS

➢Test Coil and Experiment Conditions

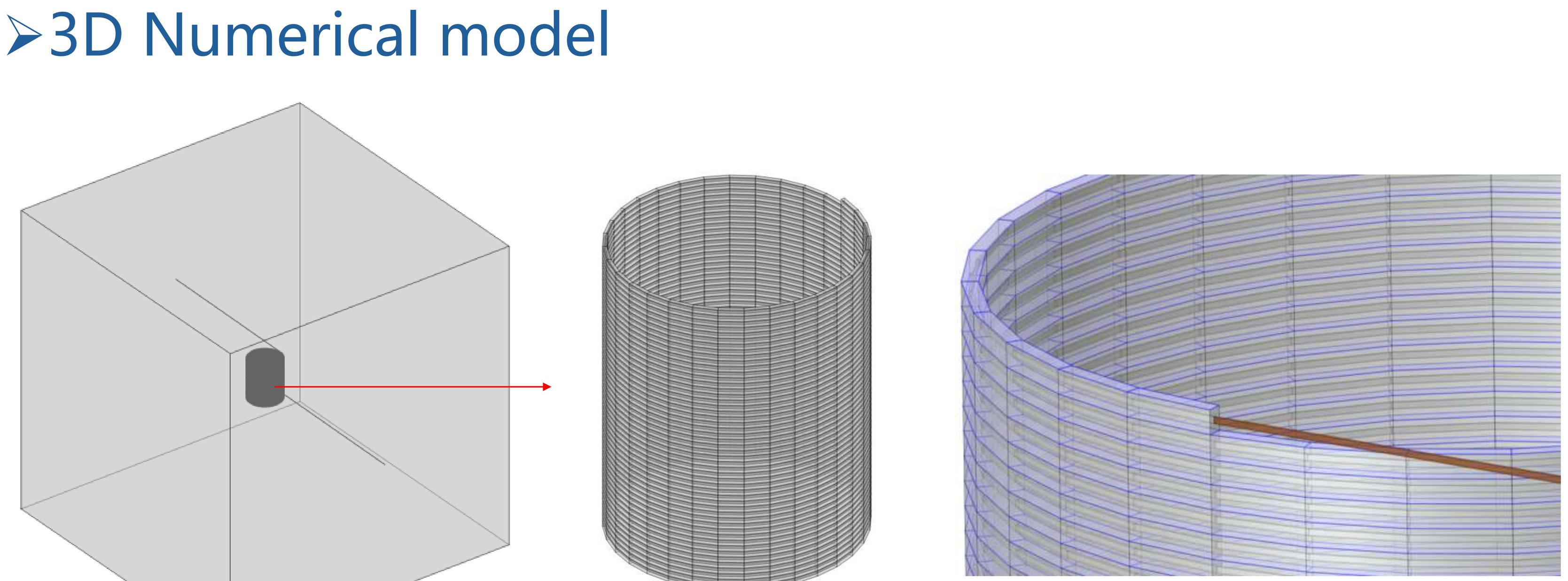


The coil was wound on a cylindrical mandrel with a radius of 300 mm, totaling 48 turns, and an axial preload was applied during winding using stainless steel strips. Performance testing was conducted with the coil immersed in liquid nitrogen, during which the current was ramped at rates of 0.2, 1, and 5 A/s up to 300 A.

Coil Parameters	Unit	Value
Cable Width	mm	15
Cable Thickness	mm	10
Number of REBCO Tapes	--	14
REBCO Tape Width	mm	4
REBCO Tape Thickness	mm	0.08
Critical current of ASTC (self-field@77 K)	A	450
Number of Turns	--	48
Inner Radius	mm	300

SIMULATION

➢3D Numerical model



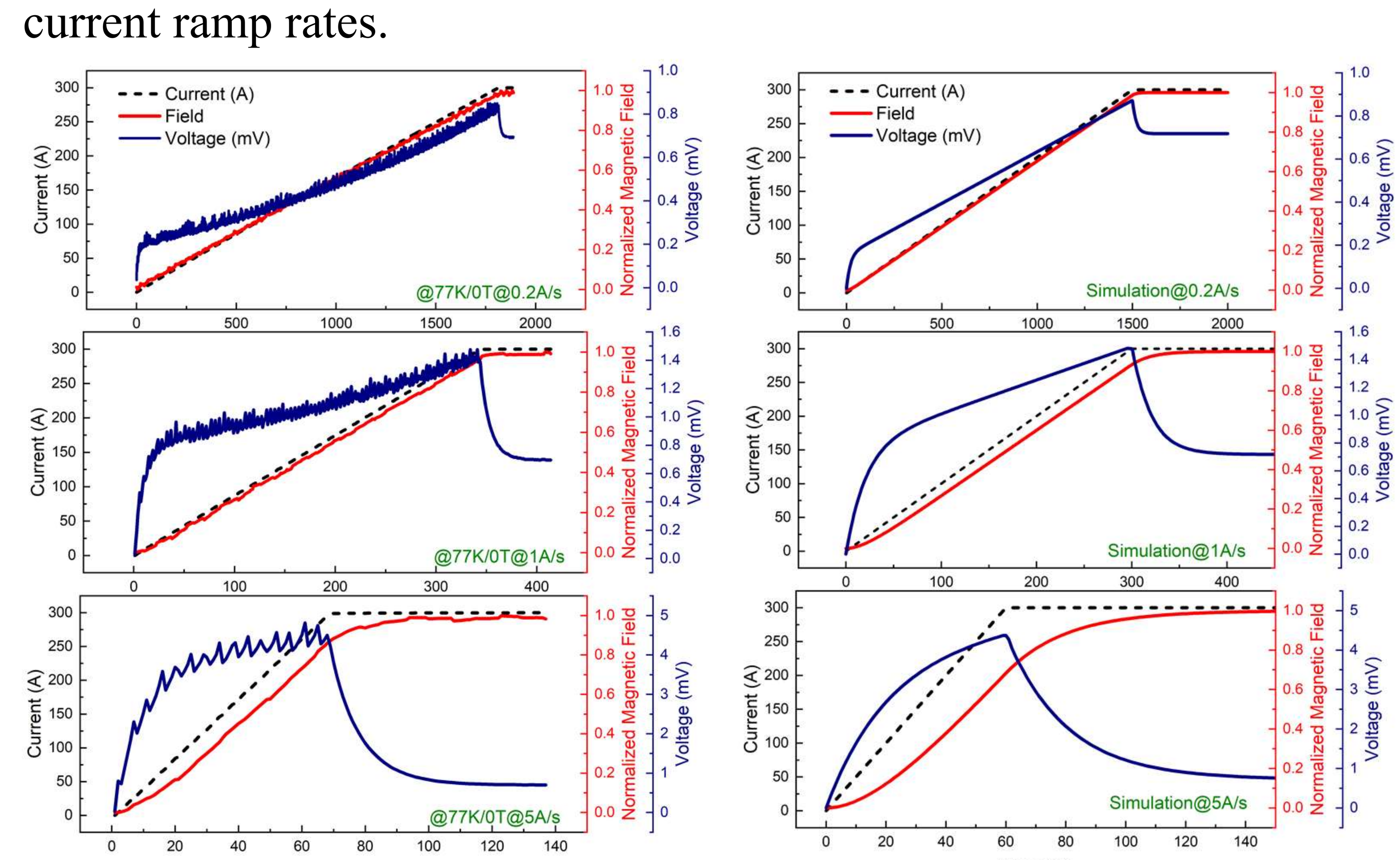
3D Coil Model

Schematic of Inter-Turn Contact within the Cable

Based on the experimentally measured surface resistivity between the superconducting tape and the adjacent turn in the cable (1.372×10^{-8} $\Omega\cdot m^2$), an equivalent inter-turn contact resistance was assigned in the model to accurately replicate the actual contact conditions during winding.

RESULTS AND DISCUSSION

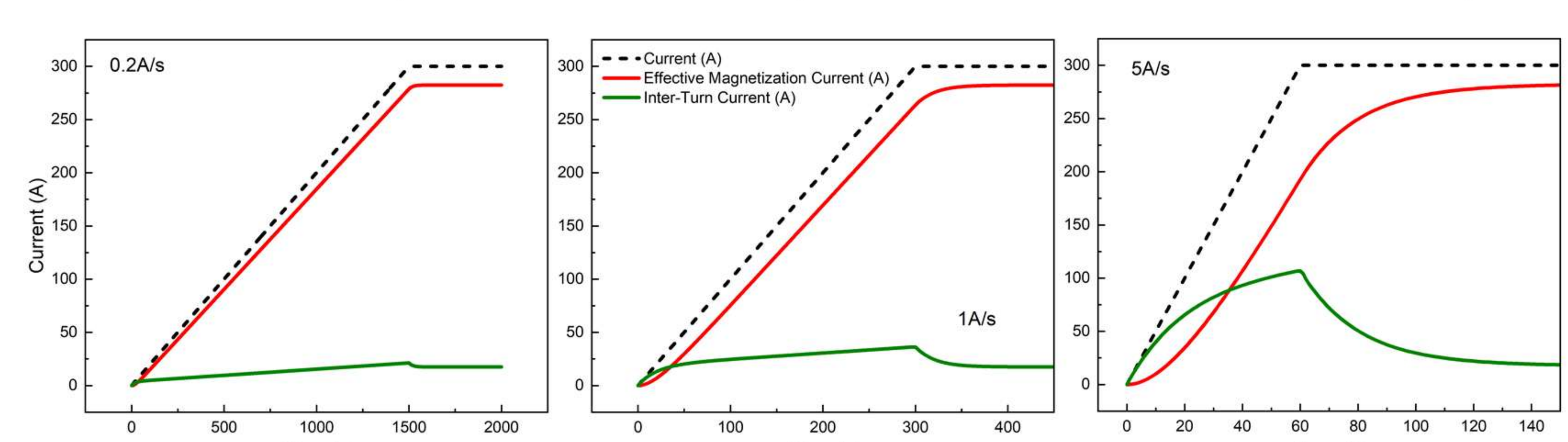
The simulation results show good agreement with experimental data, confirming that the developed three-dimensional model accurately characterizes the electromagnetic properties of the ASTC coil. The findings demonstrate that the incorporation of an aluminum stabilizer effectively suppresses magnetic field delay, as evidenced by the coil's ability to rapidly reach the target magnetic field even under high current ramp rates.



Experimental Results

Simulation Results

Higher current ramp rates enhance the inter-turn current sharing effect, leading to increased current flow through the aluminum stabilizer, thereby resulting in a corresponding rise in the coil's terminal voltage.



CONCLUSION

This study employs a combined experimental and simulation methodology to systematically examine how inter-turn contact resistance affects coil terminal voltage and magnetic field delay in ASTC coils. The findings advance the theoretical framework for understanding the electromagnetic properties of these coils. Moreover, this work establishes a solid experimental and theoretical foundation for interpreting the electromagnetic response of aluminum-stabilized high-temperature superconducting stacked cable solenoid coils, while also providing key insights for optimizing and implementing high-temperature superconducting magnet systems in the CEPC detector.