Basic study of superconducting coils in rectifier transformers for railway electrification system

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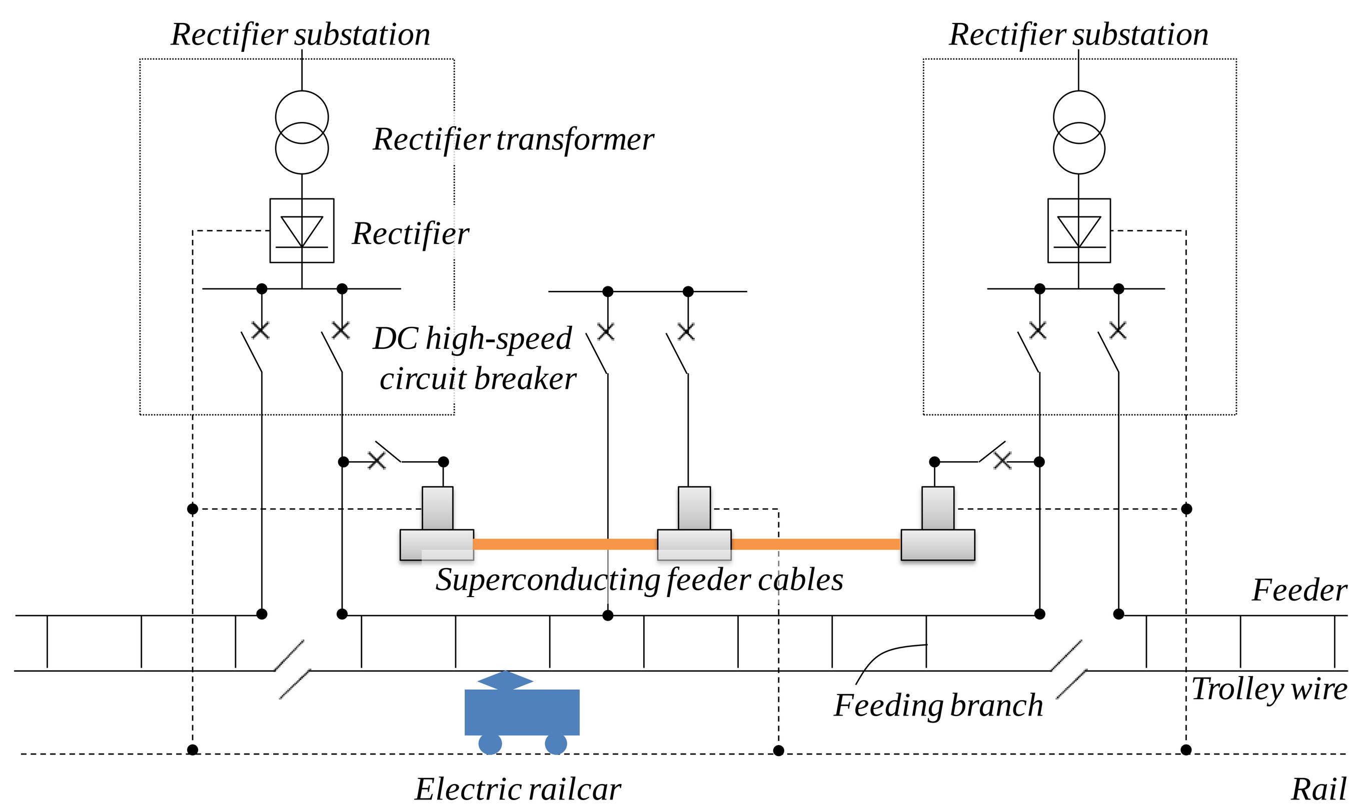
Background

Superconducting feeding system

The superconducting cables are used as a feeder, the voltage drop could be significantly reduced.

Effects
- The reduction of transmission losses
- The improvement of the regeneration factor
- The reduction of substations and so on

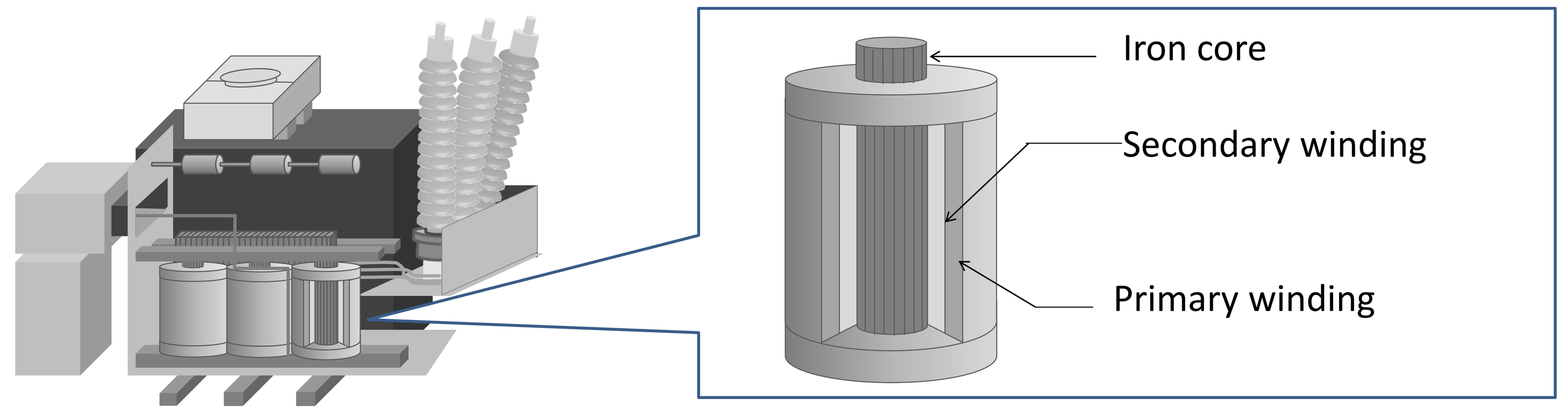
In the example of superconducting feeding systems
Superconducting feeder cable is connected between substations.
However, since superconducting cables have no resistance, fault current due to short-circuit, ground fault and so on is increased.
On the other hand, superconducting transformer with a current limiting function using a S/N transition of the superconducting windings have been developed.
When applying superconducting transformer as rectifier transformers, it is expected that the fault current is reduced.



Rectifier Transformer

Parameters of the rectifier transformer
(The capacity is 2280 kVA)

Primary Voltage	22 kV(from a power grid)
Primary Current	59.8 A
Secondary Voltage	1.2 kV
Secondary Current	1100 A



D class rating or E class rating corresponding to the specific load of electric railway is adopted.
For Example, D class rating is determined to withstand 150 % load in 2 hours, 300 % load in 1 minute.

	Continuous	150% load	300% load
Primary Current	59.8 A	89.7 A	179.4 A
Primary Current (peak value)	84.6 A	126.8 A	253.7 A
Secondary Current	1100 A	1650 A	3300 A
Secondary Current (peak value)	1555.6 A	2333.5 A	4666.9 A

Design

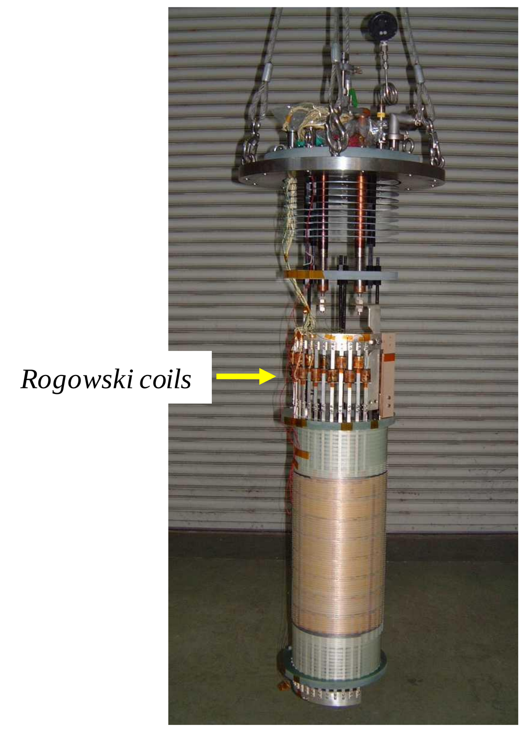
Superconducting tape (REBCO)

Thickness	**110.85 µm**
Superconductor	2.2 µm
Buffer layer (total)	0.65 µm
Substrate (Hastelloy)	100 µm
Stabilizing layer (Ag)	8 µm
Width	**5.0 mm**
Insulation layer	**35 µm**
Critical Current	**250 A (77 K)**

Superconducting winding

	Primary winding	Secondary winding
Current (300% load)	253.7 A	4666.7 A
Number of tapes	2	24
Number of turns (Layers)	1760 (8)	96 (1)
Transposition	7 times (between layers)	11 times (every 8 turns in layer)
Height of coil	1115.4mm	1137.98 mm
Inner diameter	351 mm	305 mm

Experimental

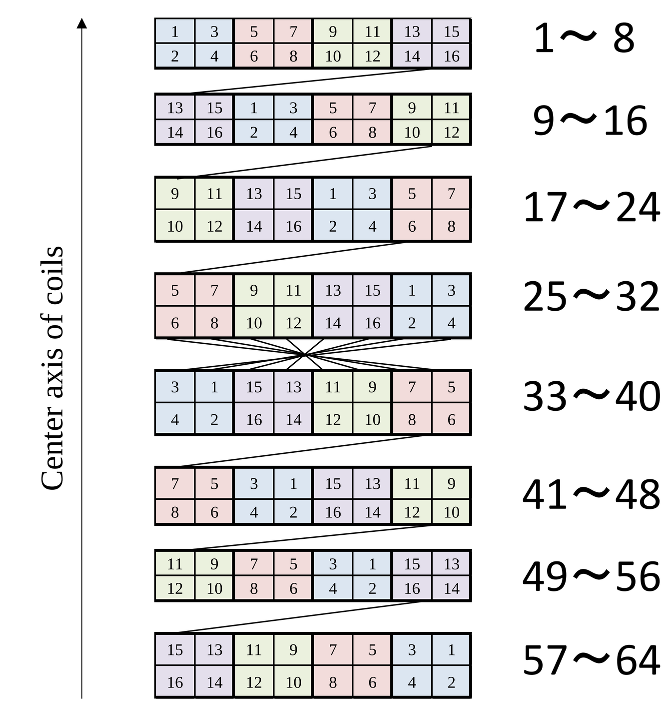


Test coil wound with a 16-strand parallel conductor

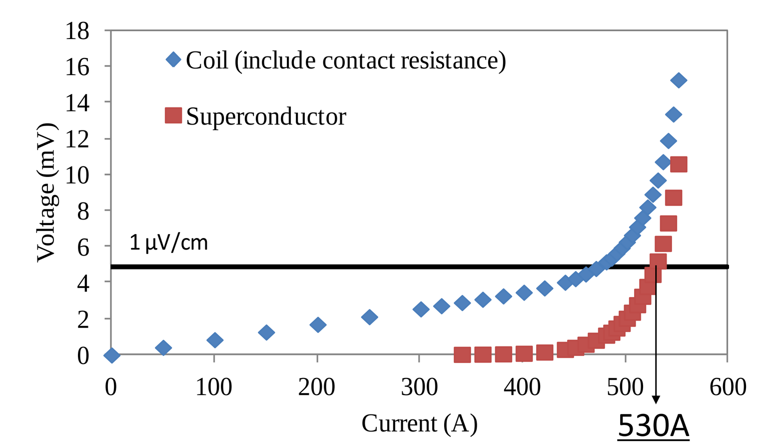
Parameters of Test Coils

Coil	
Diameter	240 mm
Number of turns	64 turns (8turns × 8blocks)
Height of winding	407.9 mm
Number of tapes	16 (8 tapes × 2 lines)
Transposition	7 times
Superconducting tapes (Bi-2223)	
Width	2.55 mm
Thickness	0.18 mm
Insulation layer	25 µm

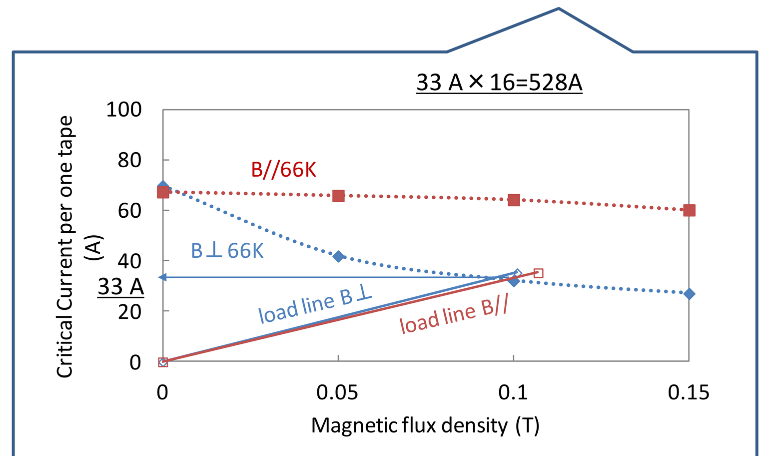
Transposition pattern



I-V curve

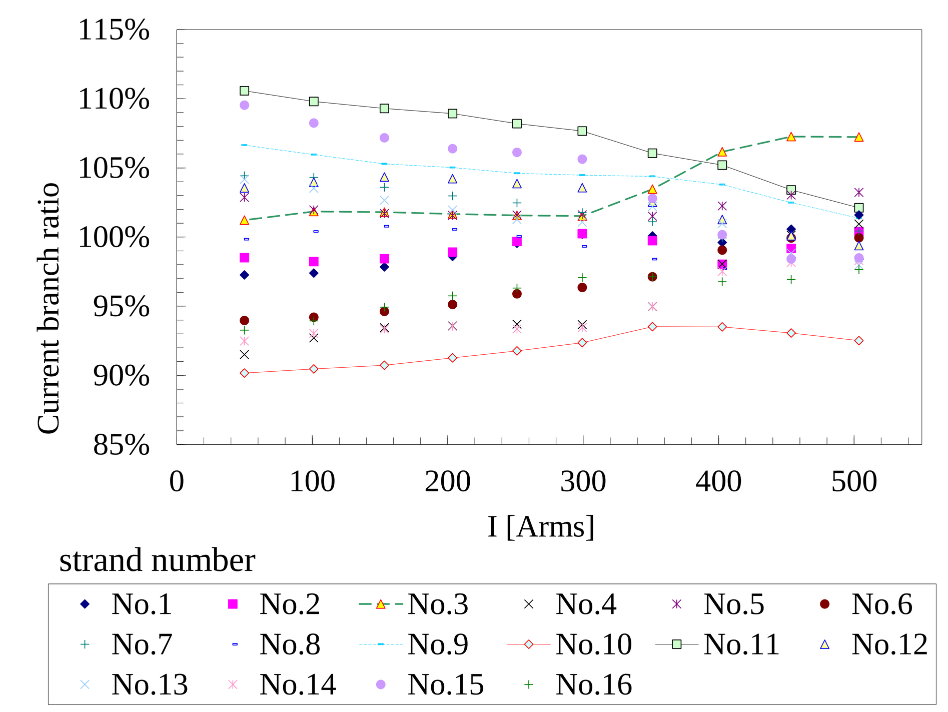


No degradation of I_c



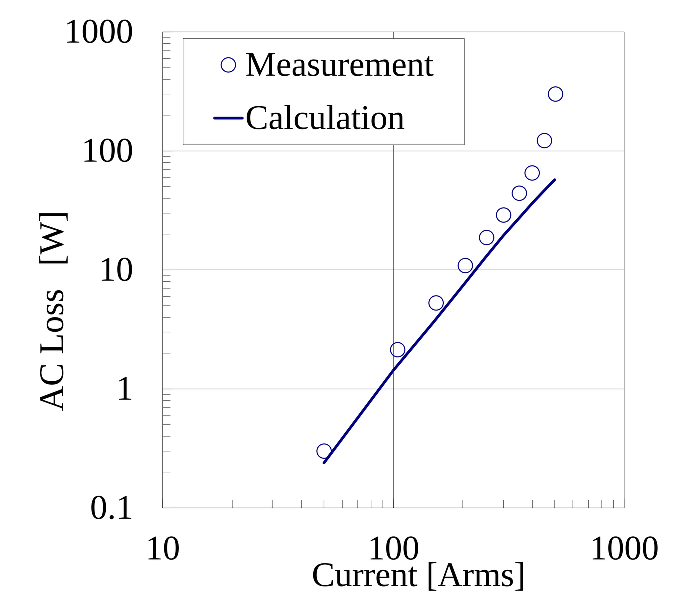
I_c-B characteristics of a tape

Current branch ratio



- The current branch ratio is within ±10%.
- Over 300Arms, the waveform was occurred distortion by the flux flow resistance.

AC Loss



- Under 300Arms, the measurement and the calculation are almost same.
- Over 300Arms, AC Loss increased by the flux flow resistance.

Conclusion

We are intending to adopt superconducting transformers with a current limiting function as rectifier transformers of railway electrification system. The secondary windings of transformers are required to have a large current capacity. To realize that, the transposition method of parallel conductors was studied theoretically and experimentally.
As the first step, the optimum transposition pattern in the case where a 32-strand parallel conductor is wound into a single-layer solenoid coil was searched for by the numerical simulation of current sharing among the strands. And then the test coil with the theoretically optimum obtained transposition pattern was wound with Bi-2223 tapes and the current sharing behavior was observed by using Rogowski coils. As a result, the validity of the found-out transposition pattern was verified.
As the next step, we are going to investigate the transposition technique of multilayer solenoid coil

Acknowledgment

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