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Development of direct current high T_c superconducting cable for railway systems

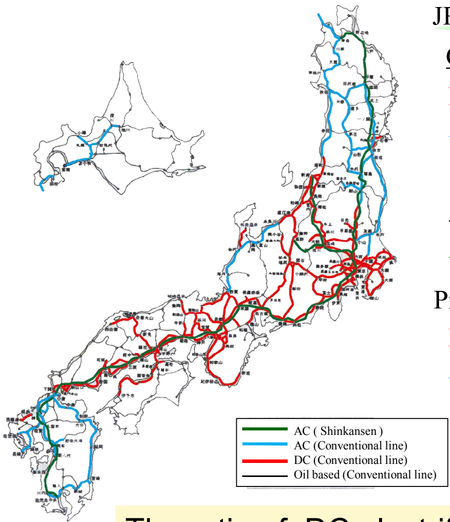
Railway Technical Research Institute (RTRI)

Masaru Tomita, Kenji Suzuki, Yusuke Fukumoto,
Atsushi Ishihara, Tomoyuki Akasaka,
Yusuke Kobayashi, Taiki Onji

Outline

(1)DC HTS electrification system for railway
(2)HTS cable development for railway in RTRI
・Prototypes of short HTS cable
・Train operation test using longer HTS power cable
(3)Future plan

Electrification System for railway in Japan



JR(Japan Railway)（ 12372.4km ）

Conventional line（ 9752.2km ）

DC electrification：65.0%(6341.4km)

AC electrification：35.0%(3410.8km)

Shinkansen（ 2620.2km ）

AC electrification：100%

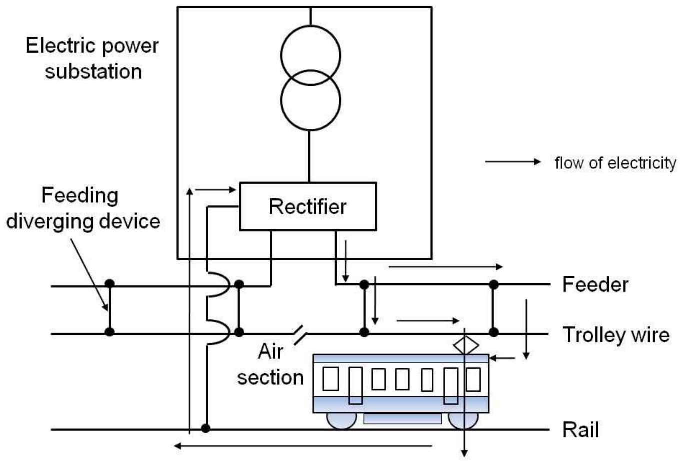
Private railway（5985.5km）

DC electrification ：91.9%(5502.3km)

AC electrification ：8.1%(483.2km)

The ratio of DC electrification is large in Japan.

DC Power Feeding System



Both the feeder and the rail bring the power to the train, and substations maintain the required system voltage around 1.5k V.

Problems in DC Electrification

・There is voltage drop in feeder circuit.
⇒ More electric power substations are needed.

・Influence of DC magnetic field to areas along the railways

・Occurrence of the electric corrosion due to the leakage current.

DC HTS Electrification

Features

Solutions
・Reduction of voltage drop
・Influence of DC magnetic field is lower
・Reduction of current leakage prevents electric corrosion

Merits
・The ratio of regeneration between trains is higher.
・It can level out the load on electric power substations.

DC superconducting cable provides
some solutions and merits for railway system

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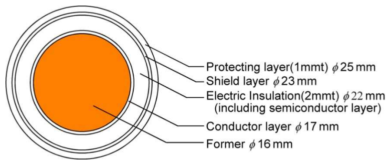
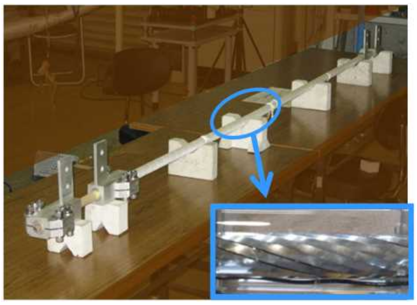
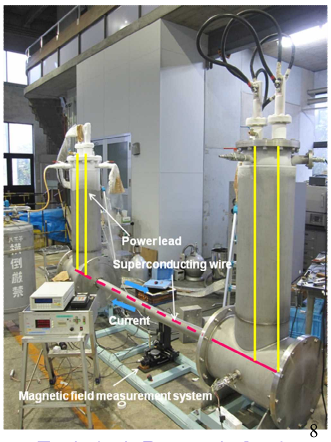
Design of 1.5kA-class HTS cable

	details
Current	1.5kA
Voltage	1.5kV
Former	Copper
Cable length	2m

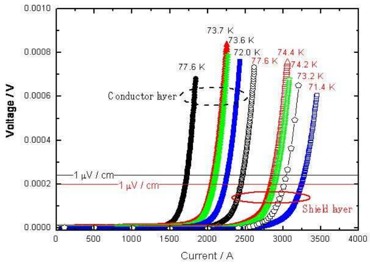






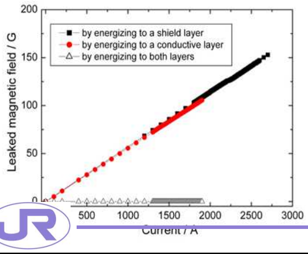
Test results of 1.5 kA-class HTS cable

Measurement results of critical current I_c of HTS cable 2 meter long in liquid nitrogen



	T / K	Critical current value / A	n value
Conductor layer	77	1720	18
	73.7	2080	16
	73.6	2110	17
	72.0	2260	17
Shield layer	77	2430	17
	74.4	2840	17
	74.2	2890	18
	73.2	3000	18
	71.4	3250	18

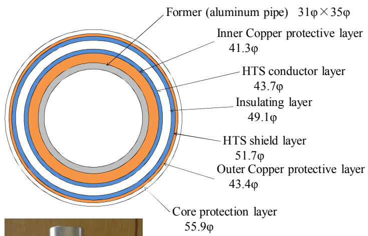
Leaked magnetic field results of shield layer and/or conductive layer

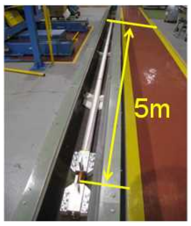


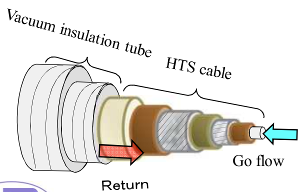
The leaked magnetic field is almost zero.

Design of 8kA-class HTS cable

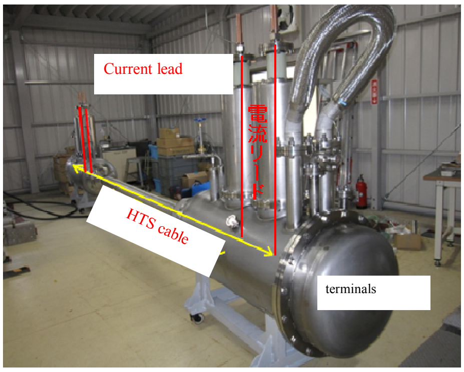
CABLE	Details
Conductor layer I_c	> 8000 A
Shield layer I_c	> 8000 A
Former diameter, D_{former}	35 mm
Inner diameter, D_{inner}	31 mm
Cu conductor layer (Inner)	3 layers / 74 tapes
HTS conductor layer	2 layers / 53 tapes
Electrical insulation	PPLP (2mm thick)
HTS shield layer	2 layers / 61 tapes
Cu shield layer (Outer)	2 layers / 65 tapes
Core protective layer	Kraft paper + cloth tape
Tape type: DI-BISCCO	50 μm copper alloy lamination
Width of tape	4.5 mm
Thickness of tape	0.35 mm
Critical Current (Ic) of the tape (at 77 K)	≥ 180 A

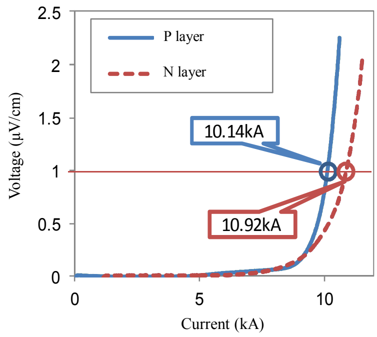






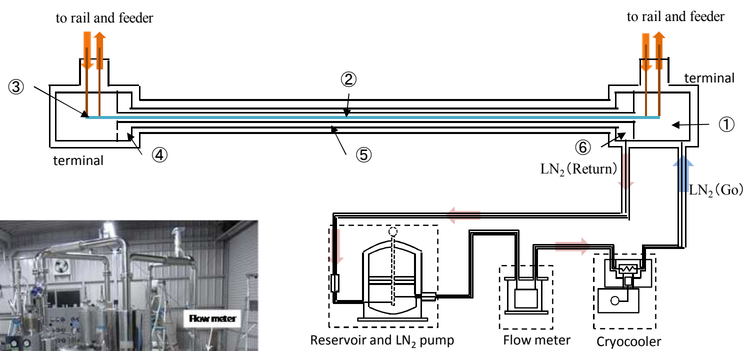
Test results of 8 kA-class HTS cable





The Ic values of both layers are more than 10kA @77.3K.

Circular cooling test of 8kA-class HTS cable



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(3)Future plan

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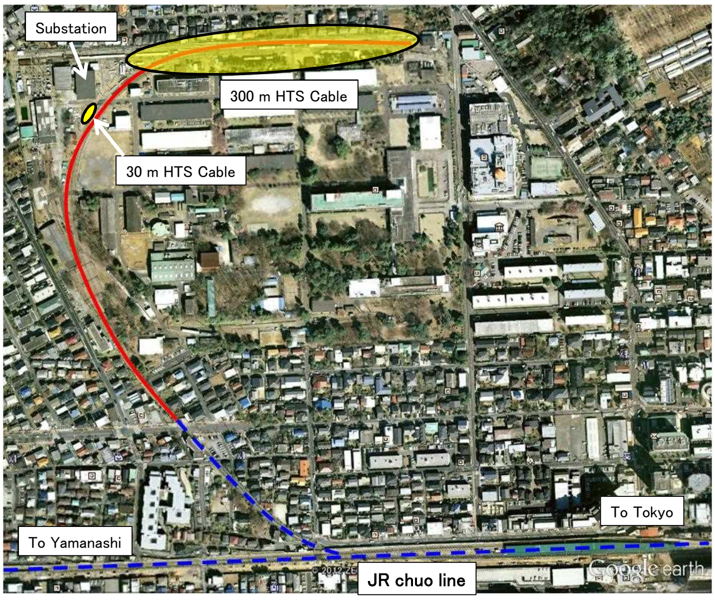
Train test truck in Kunitachi Institute



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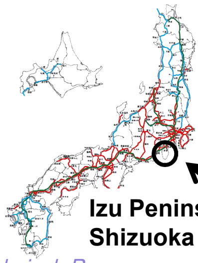
Train operation test in Izuhakone railway

Train running test was conducted on the commercial railway line using 6m HTS cable.



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(2)The HTS tape characteristics for cable design

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(4)Future plan

Field investigation in commercial railway.

Traction substation

Rail track in tunnel

We have been doing many field investigations in railway companies.

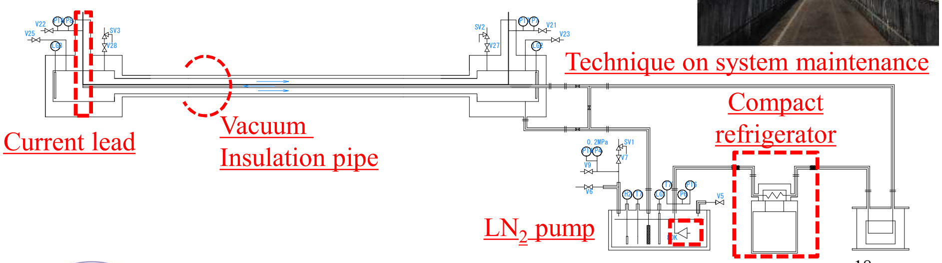
Development of the cooling technique of long distance for HTS cable (NEDO Project FY2016-FY2020)

①Development of the Main Devices of the Cooling System (Intermediate Target)

(1) Compact refrigerator (Dimensions : $2m^3/kW$)
(2) Liquid nitrogen circulation pump (Head : 0.6MPa, Flow rate:50 L/min)
(3) Vacuum insulation pipes (Heat loss : 2 W/m, Vacuum maintaining : 1 year)

②Construction and Evaluation of Long Distance Cooling System

(1) Evaluation assuming the actual environment
(2) Development of technique on system maintenance



Next step

Currently, we are preparing for test in commercial railway.
We continue to develop and adjust HTS cable for commercial use through field investigation.

Acknowledgement

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History of HTS cable development in RTRI

- 2007 ～ Research on HTS cable for railway begins. 1-10kA HTS cable were developed. [1)]
- 2013 Train running test begins on the test truck in Kunitachi Institute using 30m HTS cable. [2)3)]
- 2014 Train running test begins on the test truck in Kunitachi Institute using 310m HTS cable. [2)3)]
- 2015 Train running test was performed on the commercial railway line using HTS cable. [2)3)]
- 2017 ～2018 Train running test using 400m HTS cable 2km HTS cable is preparing.

* 2014 Collaborative research with the French National Railways(SNCF) begins.[4)5)]

End

References

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