Principal Research Results

Development of a High-Tc Superconducting Power Cable with Long Length
− Large Scale Verification Tests −

Background

A high-Tc superconducting (HTS) power cable is expected to be a candidate solution to shortages of power transmission capacity in metropolitan areas. The HTS power cable has to be cooled down below -190˚C with liquid nitrogen (LN_2) to realize the superconductivity, which enables current flow with few losses. In order to apply the HTS power cable into actual power grids, its length would be a few kilometers due to the distance between cooling stations. Therefore, verification tests have been executed for a HTS power cable with length of 500 m that could simulate the LN_2 flow properties and so forth for 5 km HTS power cable.

Objectives

To elucidate problems for the realization of HTS power cables from laying test of the HTS power cable into a testing field simulating actual cable layouts and evaluation of the installability, cooling properties, overloading properties and so forth.

Principal Results

1. Installability

The HTS power cable was laid down with a standard procedure for conventional XLPE cables to verify its installability. As a result, the HTS power cable could be laid down with a tensile stress less than the design tensile stress and no degradation was obtained in its superconductivity. Thus, no unique procedures were required in laying down the HTS power cable.

2. Cooling properties

(1) The HTS power cable was cooled down with cooled gaseous nitrogen (GN_2) firstly and then LN_2 to avoid the local concentration of thermo-mechanical stresses. As a result, the HTS power cable was cooled down for about 6 days.

(2) The HTS power cable had an offset section to absorb a thermal contraction. Its effectiveness could be confirmed from the viewpoint of cable behavior during cooling and the superconducting properties after cooling.

3. Overloading properties

(1) A voltage acceleration test was executed with a ground to phase voltage of 70 kVrms to evaluate the soundness of the electrical insulation property with duration of 1 month equivalent to 30 years. No electrical degradation could be obtained.

(2) In order to verify the operational duration in the case of faults of pumps and refrigeration system, operational tests with voltage application and current flow were carried out under a pump halt or a refrigeration system halt. Consequently, operation could be continued more than 1 hour. Moreover, the soundness of the electrical insulation property was confirmed in the overloading current region, i.e., 120 % to 140 % of design current where ac losses increase drastically.

Consequently, the HTS power cable system was revealed to have a high reliability taking into consideration many kinds of tests such as overloading tests. Moreover, plenty of knowledge was obtained for the design, testing, laying, and operation of the HTS power cable system from viewpoint of realization and application into actual grids.

Note that this test project was carried out as a part of Super-ACE (R&D of fundamental technologies for super- conducting AC power equipment) project of METI (the Ministry of Economy, Trade and Industry), being consigned by NEDO (the New Energy and Industrial Technology Development Organization).

Future Developments

Yttrium type superconducting materials are expected for larger current capacity than Bismuth type superconducting materi- als used in this project. The obtained knowledge will be totally applied to future development of superconducting electric power apparatus.

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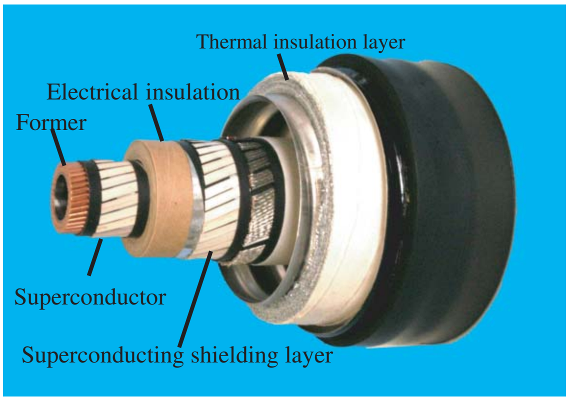
Reference

T. Tori, et al., 2004, “Research & Development of Basic Technology of AC Superconducting Power Apparatus, Research of Total System”, Technical Report H990406 (in Japanese)

T. Takahashi, et al., 2005, “Demonstration and Verification Tests of 500 m Long HTS Power Cable”, IEEE Trans. on Applied Superconductivity, Vol. 15, No. 2, pp. 1823 - 1836



Item	Construction		OD
Conductor	Former	SUS spiral tube	28mm
		Hollow copper strand wire	
	Superconductor	Bi2223 silver sheath tape (0.25 mm^t × 4mm^w)	30mm
Insulation	Insulator	Polypropylenelaminated paper	48mm
Shielding	Superconducting shield	Bi2223 silver sheath tape (0.25 mm^t × 4mm^w)	58mm
Thermal insulation	Inner pipe	SUS corrugate pipe	92mm
	Vacuum layer	Super-insulation	–
	Outer pipe	SUS corrugate pipe	124mm
	Anticorrosion	PVC	133mm

Fig.1 Structure and specifications of the HTS cable

The hollow copper strand wire for supporting the mechanical strength was arranged in the center of the HTS cable, which is called former. A superconductive shielding layer was placed outside of the electrical insulating layer to reduce the magnetic field leakage to outside of the cable. The liquid nitrogen flowed in respect of the inside of the former and the outside of thesuperconductive shielding layer.

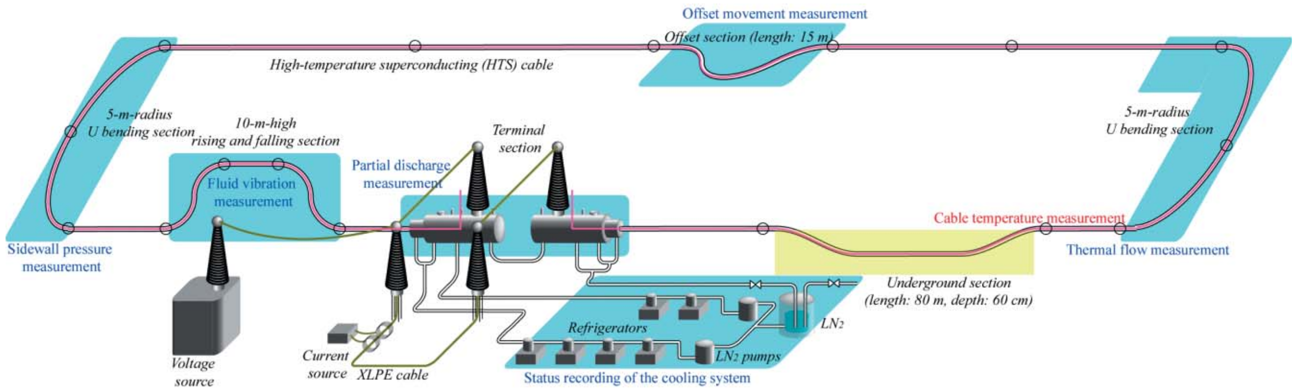


Fig.2 Layout of 500-m HTS cable testing facility

The cable layout had a 10-m-high rising and falling section simulating the river-crossing section and an offset section absorbing the thermal contraction during cooling in order to condense the features of the actual cable layouts.

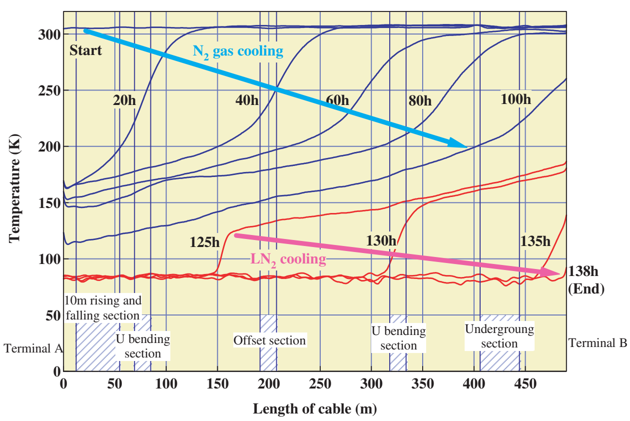


Fig.3 Temperature distribution of the HTS cable during cool-down

The HTS cable was cooled down by the gaseous nitrogen(GN_2) firstly, shown by bluecurves in the Fig.3. Then, it was cooled by liquid nitrogen after saturation of the GN_2 cooling, shown by red curves.

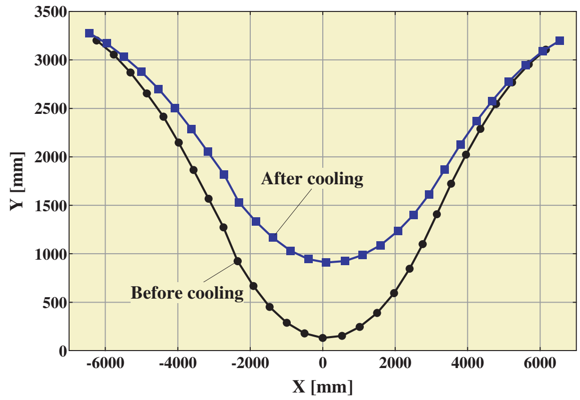


Fig.4 Behavior of the HTS cable at the offset section

Markers were put on the surface of the HTS cable at the offset section with an interval of 50 cm. Their positions wererecorded occasionally by digital cameras placed on the ceiling, which are shown by markers shown in Fig.4.