Successful Field Tests of the World's Longest 500-m HTS Power Cable

1. INTRODUCTION

A high-Tc superconducting power cable (HTS cable), which enables high-capacity power transmission with its compact size, is expected to bring about significant advantageous effects as environmentally friendly and cost effective. A 500-m long HTS cable project has been carried out as a part of the Super ACE project of METI, being commissioned by NEDO to Super-GM, in order that we have studied the details of basic operation characteristics and the issue of long distance cooling with liquid nitrogen toward practical use. A 500-m HTS cable manufactured by Furukawa Electric has been laid in the Yokosuka laboratory of CRIEPI. Furukawa and CRIEPI have been conducting since April 2004 various tests including those for installation, basic characteristics, rated loading characteristics, load fluctuation characteristics, and limiting and overloading performance.

2. STRUCTURE OF HTS CABLE

Figure 1 shows the structure of the HTS cable. The HTS cable was designed with nominal voltage of 77 kV and current capacity of 1 kA. The HTS cable had a single core structure with an HTS shielding layer and a cold dielectric type electrical insulation, outer diameter of 133-mm, which enabled to install it into an underground duct with an inner diameter of 150-mm. The copper stranded wire was adopted as a former to sustain the tensile stress up to 17-kN during installation and to keep the short circuit current capacity of 31.5-kA for 0.5-s. A conductor layer and a shield layer were comprised of Bi2223 tapes. Around the core former, intervened by an electric insulation of 8-mm in thickness. The cryostat pipe had a structure of vacuum thermal insulation whereby super-insulations were multi-layered between double corrugated pipes of SUS.

3. TEST LINE AND COOLING SYSTEM

Figure 2 schematically shows the layout of 500-m HTS power cable test system. The three-dimensional layout had several distinguishing points to simulate the actual laying configuration, such as an underground section, a 10-m-high rising and falling section and an offset section for absorbing the thermal contraction and expansion simulating the conventional underground cable laying.

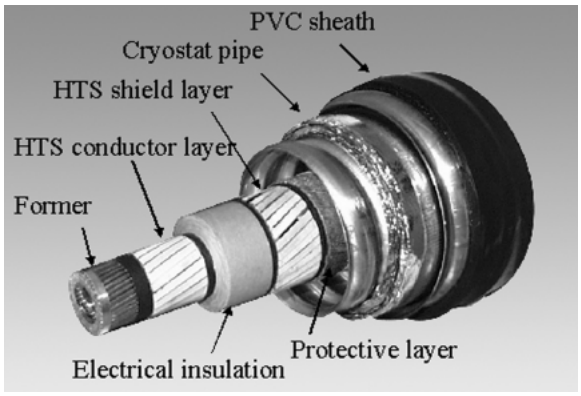

Fig.1 Structure of 500 m Cable

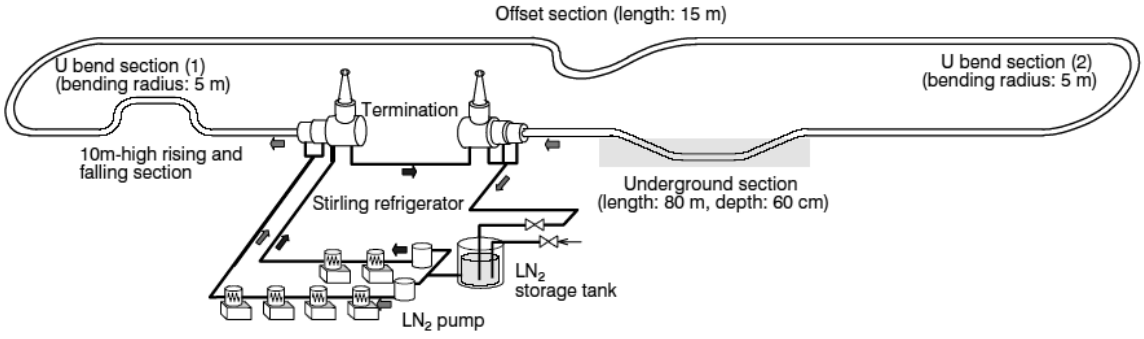

Fig.2. Schematic view of the layout of 500-m HTS power cable test system.

Fig.3. Terminals for 500-m cable tests

4. TEST RESULT

(1) Cable installation test

The cable installation was successfully executed for about 200-m duration including the 5-m-radius bending section and the underground section. A test piece that clipped from the head of the installed cable was no degradation in the critical currents before and after the transportation and the installation.

(2) Basic property test

The electrical basic properties, such as an initial withstand voltage and Ic, are shown in table 1. The HTS cable satisfied the designed specifications and was almost not damaged by the transportation, the laying and the heat cycle period.

(3) Rated loading test

A conduction current of 1000-A was continuously imposed for one month at a voltage to ground of 70-kV. These conditions were determined assuming insulation degradation in 30-years. After the one-month voltage and current loading, a 95-kV withstand voltage test was passed without occurrence of partial discharge. Thus, it was confirmed that electric insulation had good performance.

(4) Load fluctuation test

The current was made to fluctuate simulating daily load fluctuations in an actual system, and the behavior of the cooling system was investigated. Although certain amount of overshoot was observed, the system stabilized in about 3 hr.

(5) Limiting test & Overloading test

Refrigerators were stopped while continuing the rated loading test (70-kV, 1000-A), and temperature, pressure and partial discharge of the cable have been monitoring. The pressure reached its limitation first in 3 hr 30 min. In addition, all cooling function including refrigerators and pumps was halted for one-hour, keeping rated-power loading. No P.D. was detected and no problem occurred in both conditions.

Table 1. Results of basic property tests

Item	Value
Ic of the conductor	1570 A
Ic of the shield	1350 A
Withstand voltage	95 kV for 10 min
P.D. test	No P.D. at 95 kV Noise level of 100 pC.
Heat invasion	1.2 W/m
AC losses	1.3 W/m at 1 kA

5. CONCLUSION

The HTS cable withstood all the items of this field test without being damaged. It has been confirmed that the cable had high reliability because the cable has withstood various tests. The important achievements have been accomplished through this series of tests, and obviously contribute to practical applications of the HTS cable in terms of design, testing, installation and operation.

Reference

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http://www.furukawa.co.jp/review/fr028/fr28_10.pdf

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