AP5-1-INV

Design of AC 23kV 50MVA Class HTS Cable in S. Korea

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The world first commercial project for superconducting applications is already starting in S. Korea. The first step of named **SSS** (**S**uperconducting **S**mart platform **S**tation in S. Korea) project is to operate AC 23kV 50MVA class HTS cable system in power grid of Korea Electric Power Corporation (KEPCO) in order to increase power capacity and stable operation. This HTS cable system connects two substations between ShinGal and HeungDuk. Total length of HTS cable is approximately over 1km with 2 sets of normal joint box and 2 sets of termination which are outdoor type accessories for HTS cable system.

Before performing the type test, various preliminary tests with the short core were performed to confirm the HTS cable design. To meet design target values, HTS layers of each phase core consist of two conducting and one shield layer with non-magnetic 2G wire to reduce magnetization loss by adjacent HTS wires. Measured AC loss is around 0.3W/m at 1,255Arms and increasing trend of AC loss due to operating current is well fitted simulation results. In case of short-circuit test, reached maximum temperature at 5.5 bar.g is under 96.5K which is enough below boiled temperature of LN_2 at above pressure condition. A 100-meter HTS cable including unit test samples and 110-meter LN_2 return pipe were manufactured and installed for type test at KEPCO Power Training Center in Gochang, S. Korea. Type test is including various sample tests, 20 cycles load test, voltage tests such as AC withstand and impulse, repeated cooling process three times and visual inspection after disassembling. In the first quarter of 2018, LS Cable&System will supply and install AC 23kV HTS cable system in S. Korea.

Keywords: 23kV 50MVA class HTS cable, AC loss, short-circuit test, type test

AP5-2-INV

DEVELOPMENT OF TRI-AXIAL SUPERDONDUCTING CABLE SYSTEM

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We developed tri-axial superconducting cable system with the rated voltage of 35kV and operating current of 3kA at liquid nitrogen temperature. We designed superconducting cable, termination connection and cooling system with using overcooled liquid nitrogen. We used in-house YBCO tapes and a winding machine to prepare conductor having the *Ic* -value of 4,200A or more per phase at liquid nitrogen temperature. The outer diameter of the conductor and cryostat was approximately 50mm and 130mm, respectively. The length, diameter and weight of each termination connection are approximately 2,500mm, 700mm and 350kg. The thickness of the insulation layer, which was PPLP paper, was determined by estimation of minimum break down electric field with Weibull distribution analysis of results for break down tests of the model cable. Regarding the cooling condition of cooling system, the liquid nitrogen temperature of inlet and outlet of cable system was designed to be 65K and 70K, respectively. We manufactured 25m tri-axial superconducting cable and cut 2m out of it for critical current test and voltage test at liquid nitrogen temperature. The critical current of each phase was higher than 4,500A. There was no break-down of each insulation phase with 53kV for a 30minute at the voltage test. We also manufactured a pair of termination connection for system test and no break-down occurred each insulation phase with 53kV for a 30minute. Based on fundamental performance test, we performed type test of cable system with building up cable system including superconducting cable, termination connection and cooling system based on "Recommendations for Testing of Superconducting cables (CIGRE Technical Brochures 538)".

This paper is based on results obtained from a project subsidized by the New Energy and Industrial Technology, Development Organization (NEDO).

Keywords: Superconducting cable system, Tri-axial, Teremination, Overcooled liquid ntrogem

AP5-4-INV

Flywheel Energy Storage System Using Superconducting Magnetic Bearing for Demonstration Test

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The principle of the Flywheel Energy Storage System is simple, and there are already examples of its use within Japan. Some of these have been used for over 20 years, however, it was the problems with the bearings that obstructed wide spread dissemination. In order to increase storage capacity, it is necessary for the bearing to be able to withstand a high load and high-speed rotation, but there is no conventional bearing which can withstand these demands.
In light of this, RTRI has invented superconducting magnetic bearings with superconducting coils and bulk superconductors. We have developed a superconducting magnetic bearing utilizing a strong magnetic repulsive force by a combination of REBCO wire coils that generates more than 6 Tesla and large single crystal REBCO bulks. Then we demonstrated that 4 tons of flywheel can be supported non-contact and rotated to store energy. The experiment was conducted at the “Next Generation Flywheel Power Storage System Verification Testing Facility” at the Komekurayama Solar Power Plant in Yamanashi Prefecture. Various verification tests are been carried out the same facility, of various related technologies to hasten the practical application of the superconducting magnetic bearing.
This development was supported by NEDO in a part of "Development of next generation flywheel energy storage system".

Keywords: Flywheel, Magnetic bearing, Energy storage, High-temperature superconductivity

AP5-5-INV

Liquid hydrogen system toward hydrogen Society

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In Japan, hydrogen energy society is expected for CO2 (Carbon dioxide) reduction and energy security. In the future, hydrogen utilizations will become larger from fuel cell vehicles to hydrogen generating turbines, so that a large amount of hydrogen introduced into society is comparable to the current LNG (liquid Natural Gas) consumption. According to "The Strategic Road Map for Hydrogen and Fuel Cell" released in 2016 by the Japanese government, we will import CO2-free LH2 (liquid hydrogen) will from overseas countries having hydrogen source around 2030s. LH2 has not only chemical energy but also cold energy, differing from other hydrogen carriers (organic hydride, ammonia, etc.) for transportation and storage. This advantage can make it to be refrigerant of superconducting cooling system.
In this paper, I will describe the outline of a large scale LH2 system consisting of a hydrogen liquefier, a loading LH2 site, a LH2 carrier, a unloading LH2 site. And also, their related laws and regulations, LH2 safety technologies, and LH2 refrigerant for cooling superconducting magnets will be described.

Reference:
・METI, "Strategic Road Map for Hydrogen and Fuel Cell" (2016), in Japanese

AP5-6-INV

Progress in the development of refrigerator for HTS Cable

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The demonstration test of Yokohama project, the operational stability and long term reliability of the HTS cable system in a real grid was verified [1]. The test was successfully, but some problems related to the Stirling refrigerator have been revealed. Then, a high performance refrigerator has been developed in this project. Target values of the refrigerator are cooling capacity of 5 kW and COP of 0.1, maintenance interval of 30,000 hours. To achieve a cooling capacity 5 kW and COP 0.1, the reverse Brayton cycle is adopted, employing a turbo compressor and a turbo expander. Magnetic bearings are used in the compressor and expander to increase the maintenance interval to over 30,000 hours. This refrigerator was confirmed to have a cooling power of 5.8 kW and COP 0.1 at 77 K. The demonstration test utilizing the refrigerator in Asahi substation is underway.
To prioritize COP 0.1 of the refrigerator, pressure drop of heat exchangers was reduced. The size of the heat exchanger and the refrigerator was increased. More compact refrigerator commercial base is developed for practical use of HTS cable. Figure 1 shows Brayton refrigerator commercial base. The size of refrigerator is reduced to 35 % compare with the refrigerator for demonstration test in Asahi substation.
The progress in the development of Brayton refrigerator for HTS cable is outlined in this presentation.

[1] S. Honjo, et al., "Status of superconducting cable demonstration project in Japan," IEEE transactions on Applied Superconductivity, vol.21, 2011, pp.967-971.

Keywords: HTS Cable, Brayton cycle, Refrigerator