§16. Study on 1 GW Class Hybrid Energy Transfer Line of Hydrogen and Electricity

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The design principles of hybrid energy transfer line (HETL) of hydrogen and electricity are, 1) low energy consumption system for long transportation, 2) power line of low-voltage and high-current system (+/- 50 kV, 10 kA), and 3) integrated energy transportation system (liquid H_2 of 100 tons/day) [1]. It is desired for the new needs which combine hydrogen fuel and SC power transmission.

The HETL system requires high reliability and safety as well as the conventional power grid and natural gas pipe line. The SC cable should have the large margins for the operation current in the limited cross-section. The SC materials should have the requirements, (1) which can expect reduction in manufacturing cost, (2) which can be used in the temperature range of 17 K - 24 K, and (3) which is simple for manufacturing and can keep seeing enlargements. Magnesium diboride (MgB2) wire is one of the potential candidates for 10 kA class cable, since the core Jc of more than 1000 A/mm^2 under the liquid helium was observed in various MgB2 wires. The 10 kA class SC cable for the HETL was designed on the basis data of the MgB2 wires with a diameter of 1.3 mm . Operation current of a MgB2 strand at liquid hydrogen temperature was determined to 20 A (core Jc=100 A/mm2).

Cross- sectional view of the HETL is shown in Figure 1. Two types of structure were investigated; one is bath cooling method (Type A), and the other is hollow type conductor (Type B). The application of type A leads to an easiness of the assembling work and an enlargement of the liquid hydrogen area. On the other hand, application of type B leads to a decrease of the magnetic field in the cable and an increase of heat transfer between cable and liquid hydrogen. Both types of SC cable structures are acceptable for a cryogenic envelope of the HETL. As shown in Fig. 1, transfer line consists of the SC cable, space for liquid hydrogen, electrical insulation layer, inner corrugated tube, vacuum space for thermal insulation, outer corrugated tube and so forth. Pressure loss ΔP is expressed by following Fanning's equation.

$$\Delta P = 4\lambda\rho\frac{v^2}{2}\frac{L}{D} \quad (1)$$

Where, λ is friction factor and ρ is density, and v is velosity of H_2. The calculation result of the pressure loss as a function of pressurized hydrogen temperature is shown in Figure 2. When the pressure of liquid hydrogen increases, boiling temperature becomes high. Pressurization of liquid hydrogen enables to expand operation temperature region of the MgB2 cable, and to absorb the head loss of the installation route. In order to obtain the operation temperature of MgB2 cable from 17 K to 25 K, the pressure of liquid hydrogen from 0.4 to 0.6 MPa was chosen. Reduction of the heat load into the transfer line is one of the important subjects to realize the high-efficiency HETL system. Following are effective methods to reduce the heat leak between the corrugated tubes, (1) high vacuum degree (1x10^{-5} mbar) against heat leak due to convection, (2) increase in number of super-insulation (SI) sheet against heat leak due to radiation, and (3) slender and long spacer against heat leak due to conduction. When a heat load is 1 W/m, the temperature rise is 2 K. Even if the heat load is 2 W/m, the cryostable condition can be sustained, when the inlet temperature is less than 20 K.

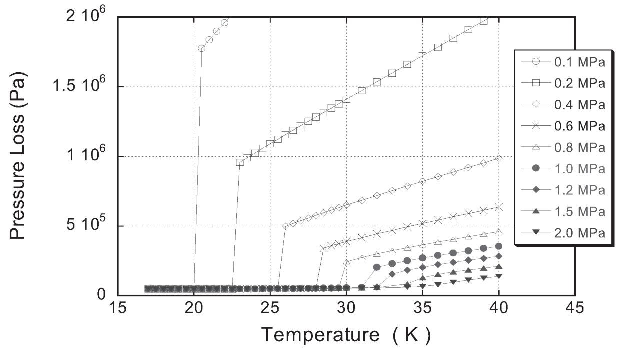

Fig. 2. Pressure loss of 10 km long HETL as a function of temperature of pressurized hydrogen.

1) S. Yamada et al: Journal of Physics: Conference Series 97 (2008). doi:10.1088/1742-6596/97/1/012167

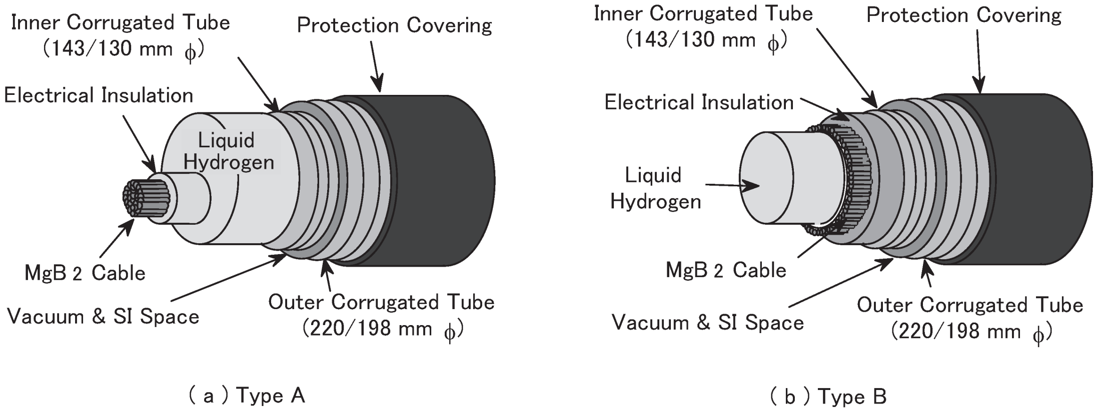

Fig. 1. Schematic drawings of the HETL: (a) twisted SC cable with 500 strands, and (b) hollow-type SC cable.