DEVELOPMENT OF 275 KV 3 KA HTS POWER CABLE

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ABSTRACT

HTS cables can reduce transmission loss for use instead of conventional transmission lines. The transmission loss of the HTS cable consists of AC loss in a conductor and a shield, as well as dielectric loss, heat invasion loss in a cryostat pipe, and cooling system loss. AC loss and dielectric loss in the electrical insulation of the cable were treated in the first step of R&D for HTS cables. Concerning AC loss, we found critical current uniformity in the lateral direction of the tape strongly influenced the AC loss. YBCO tapes 3 mm in width, which had uniform current distribution in the tape, were used in order to fabricate a conductor sample for AC loss measurements. The AC loss achieved 0.12 W/m at 3 kArms with the world's lowest AC loss. Moreover, concerning dielectric loss, the cold dielectric insulation composed of liquid nitrogen and polypropylene (PP) laminated paper is regarded as a low dielectric loss insulation for HTS cables because it has a low tangent delta. Moreover, dielectric properties, such as the withstand voltage, and partial discharge property, have been investigated for the 275 kV HTS cable design. The validity of the design has been demonstrated in high voltage tests in the 275 kV class.

KEYWORDS

AC loss, Coated conductor, High voltage, Power cable, Termination

INTRODUCTION

High-temperature superconducting (HTS) cables are considered the next generation of transmission lines because they are compact, lightweight, and demonstrate large capacity and low loss compared to conventional cables. In particular, since YBCO tape called coated conductor or 2G wire provides high critical current, high magnetic-field properties, and low AC loss at low cost, the HTS cables are expected to become more attractive than other superconducting wires. YBCO HTS cables at 275 kV 3 kA were developed in the Materials & Power Applications of Coated Conductors (M-PACC) project supported by the New Energy and Industrial Technology Development Organization (NEDO)[1]. HTS cables have the largest transmission capacity at 1.5 GW among cables that have ever been developed in the world. HTS cables have the potential to be put to practical use as the backbone power line in the future because the capacity is almost the same as overhead transmission lines.

EFFECT OF INTRODUCTION OF 275 KV HTS CABLE

Typical Japanese power networks from power plants to consumers are constructed of overhead lines from power plants to the urban areas and underground lines within the urban areas that have 500 kV or 275 kV transmission voltage. Overhead transmission lines transmit power long distances from the power station to the first substation located just outside a city. In the overhead transmission line here, electric power of several gigawatts is transmitted, and it is thought that the demand for gigawatts-class underground cables increases when thinking about the connection of an underground cable to an overhead line. However, the power transmission capacity of conventional XLPE cables and OF cables is dealt with in several hundreds of megawatts because of the restrictions of current transmission heating. Two or three circuits of conventional cables need to be installed to obtain a transmission capacity of 1500 MW. A 275 kV 3 kA HTS cable (Fig. 1), which is the target of this project, will be put to practical use as a backbone power line in the future[2]. The transmission loss of the XLPE cable consists of conductor loss and sheath loss. The sheath loss is eddy current loss in the sheath metal, which is induced by an alternative electrical magnetic field from the other phase cables. Since sheath loss depends on the alignment of three-phase cables, we calculated the lowest sheath loss where the three-phase cables were arranged in three straight lines. HTS cables do not induce eddy currents in other cables because of the electro-magnetic shield effect of the HTS shield layer. HTS cables can be installed in the shape of a triangle and do not take space compared with XLPE cables in underground tunnels. HTS cables can transmit electrical power of 1500 MW on one circuit line, and it is possible to lay it in 1/3 less space than XLPE cables.

Table 1 shows the analytical values of transmission loss on a 275 kV HTS cable and a 275 kV XLPE cable line that can transmit electrical power of 1500 MW. The transmission loss of three XLPE cables (1cct; one circuit) set in parallel is 60 kW/km. Transmission losses of HTS cables consist of the AC loss of the conductor and the shield, dielectric loss, heat leak loss of a cryostat pipe, and cooling system loss. We estimate that the total loss of HTS cables as AC loss and dielectric loss is 0.8 W/m/ph, the heat invasion loss of the cable cryostat pipe is 1.0 W/m/ph, and cooling system efficiency is 0.1. The total loss of the HTS cable is 54 kW/km, which will be drop to 1/3 less than the XLPE cable[3].