Field Test of 3 phase, 22.9kV, 100m HTS Cable System in KEPCO

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Abstract. Starting from investigation of feasibility and basic studies, KEPCO/KEPRI has carried an enterprising project for HTS cable system since 2002. The objectives of this project are to demonstrate HTS cable system and evaluate the feasibility in electricity utility’s view. The installation of 100m/3phase/22.9kV/50MVA HTS cable system is undergoing in KEPCO’s test yard, located in Gochang, Korea. The HTS cable system consists of 100m long cable, two terminations and a cooling system. To simulate the actual cable installation, the 55m section of the 100m long cable was installed into an underground tunnel. Commissioning test is scheduled at the end of September, 2005 and followed by long term operation test. In this paper, the installation of HTS cable system and initial results of system operation will be summarized

1. INTRODUCTION

High Temperature Superconducting (HTS) cable is a promising alternative for conventional cable in terms of lower transmission loss, lower impedance and less right-of-way. [1] Especially, the point of three to five times’ higher capacity without raising voltage is very attractive for utilities. In metropolitan region like Seoul, to obtain right-of-way becomes difficult gradually. If underground transmission cable is replaced by an HTS cable, it will not only solve the problem of right-of-way but also be advantageous economically because less right-of-way and less construction expenses are needed.

Korea Electric Power Corporation (KEPCO) is seeking for multiple solutions to handle the increasing needs for power supply. As one of the solutions, with the support from Korean government and KEPCO, an HTS cable project has been initiated in 2002. Basic research and investigation of the validity were performed for two years and then the world’s first commercial contract for HTS power cable via international bidding was made with Sumitomo Electric Industries (SEI) in August, 2004. Commercialization era of HTS cable was finally opened.
The HTS cable system installation is underway since July, 2005 and is planned to end in September, 2005. This cable system is composed of 100m/3phase/22.9kV/50MVA class HTS cable, two 3-in-one terminations, and open loop type cooling system. This system is manufactured by SEI. The cable system including the cooling system is installed at Gochang test yard, Jeonbuk province Korea. Site-layout under installation is shown in fig 1. Korea Electric Power Research Institute (KEPRI), which is a R&D organization of KEPCO, will integrate the systems, carry out long term tests and evaluate the test results with the criterion of power utility.

2. OVERVIEW OF KEPCO/KEPRI PROJECT

The goal of the project is to evaluate the technical and economical feasibility of an HTS cable system in the KEPCO grid. This is particularly important because cryogenic temperature is very unfamiliar to an electric power company. The main objectives in this project are:

1) Acquisition of HTS cable operation technology
2) Evaluation of overall HTS cable performance including cooling system
3) Compatibility between conventional cable and HTS cable
4) Economical efficiency

The project team is composed of three institutes and three universities. The prime supervisor of the project is KEPRI, which supplies test site, manages HTS cable project and consistently leads plans for the HTS cable. Korea Electrotechnology Research Institute (KERI) supplies engineering service for total system installation and takes charge for measurement system. Korea Basic Science Institute develops standard of the cooling performance and supports operation of the cooling system. Chunnam national university conducts a research on evaluation technology of AC loss. Chunbuk national university conducts a research on over-current phenomena. Chungbuk provincial university of science & technology develops a technology for utility line interconnection of HTS cable. The HTS Cable carries three phases in a single cryostat. The cable is made of defect free CT-OP wires. Three-in-one type termination and open-loop cooling system without refrigerator are adopted in this project. To be taken into consideration of compatibility with conventional 22.9kV, KEPCO/KEPRI cable is rated for 22.9 kV and outer diameter is 130mm applicable for 175mm ELP duct. The cable is designed to handle the fault current of maximum 25kA for 5 cycles. Total length of cable is 100 m including the underground section of 55m. To simulate the practical cable installation, bending angle of HTS cable was maintained at 27° at inlet and outlet part of duct and minimum bending radius is kept not greater than 5m. The cooling system was designed to be operated at 77K below.

3. STATUS TO DATE AND FUTURE SCHEDULE

According to the scheme of the project, all infrastructures such as a new building for HTS cable and a superconducting fault current limiter (SFCL), cooling facility building, pit for return pipe, 5 ton CE tank and associated civil works for the HTS cable installation had been constructed since October, 2004. Prior to shipment of the HTS cable system, factory inspection tests were performed in Osaka Works of SEI for the items which are shown in table 1.
Table 1. Results of factory inspection test.

| Test Type                        | Result                                      |
|----------------------------------|---------------------------------------------|
| AC Withstand Voltage Test (5m cable) | No breakdown at 45kV                       |
| AC Impulse Test (5m cable)       | No breakdown at ±150kV, 10 shots            |
| Critical Current (5m cable)      | 1800A                                      |
| AC loss test (3m cable)          | 1.18W/m at 1000A                           |

The whole system was shipped from Osaka, Japan to Busan, Korea about 640 km by ferry and then was transported to Gochang test yard about 360 km by air suspension trailer. The weight of total cargo amounted to 15 tons. To monitor whether damage is occurred during transportation, vibration measurement equipments were attached to both terminations and one cable drum. As planned, the HTS cable was installed into existing duct in same manner as conventional method with winches and caterpillars. The 55m cable of underground section is put on the tray. Fig 2 shows the view of cable pulling works.

Once cooling system installation was finished, the initial cooling test without HTS cable was conducted. To simulate the heat invasion of full system, heat load of 1.8 kW was applied to the reservoir unit by heater. Cooling system and results of the test are shown in fig 3 and fig 4, respectively. Deviation of inlet temperature from the designed temperature is below 2 K, which is considered to be stable. The procedure to get cryogenic temperature is described as follows.

1) Liquid nitrogen from CE tank is transferred into the gas/liquid separator.
2) Liquid nitrogen under the saturation vapor pressure state is obtained by decompression units at a subcooler.
3) Liquid nitrogen that is circulated through the HTS cable flows into the reservoir unit. It is to be pressurized into subcooler by pumps, where heat exchange occurs.

All parameters such as pressure, temperature, flow rate and level of LN₂ were monitored, controlled and gathered in the cooling facility building. Upon completion of the assembling works of terminations, every point which was welded and assembled was checked by air tight test, foaming test and He leak test in order to confirm the soundness of vacuum. Now pre-cooling test of total system is ongoing. Test equipments for voltage & current loading and measurement equipments will be set by middle of September, 2005. The items which will be tested after installation are listed in table 2.
Table 2. Items of after-installation-test

| Item                               | Specification          |
|------------------------------------|------------------------|
| AC withstand voltage test          | 33kV for 5min          |
| Critical current measurement       | 100 m full length      |
| Heat loss measurement              | at 1250 Arms           |
| Shield current measurement         | Rogowski coils         |
| Dielectric evaluation              | Measurement of capacitance and tanδ |
| Temperature profile                | Optical fiber thermometer |

Fig 4 Results of initial cooling test

When after-installation-test is finished, performance test will be conducted with the condition of 48 hours continuous operation. If it is completed successfully, “Notice of Acceptance” (NOA) will be issued to SEI.

This project will be ended in February, 2006. Other tests to be performed include: real-time remote monitoring and operating system, that equipped with alarming function to alert operators of possible failure and emergency states, load cycle test and long term operation test.

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