§8. Evaluation of Electrical Insulation Properties of Superconducting Coils

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A superconducting coil of LHD is exposed to various stresses, such as a thermal, electrical or mechanical one. Electrical insulation systems of LHD are placed in liquid helium, and when transition from superconducting state into normal conducting state called quench occurs on superconductors, it is possible that its electrical insulation strength is significantly reduced by the vaporization of the liquid helium due to the Joule heat at the quenched part of the superconductors. These cryogenic environments and the quench phenomena must be taken into account in the electrical insulation design as well as in high voltage tests of LHD. As the first approach to this issue, this project focused on power frequency withstand voltage tests of HTS (High Temperature Superconductor) power apparatus with pancake coil structure cooled by liquid nitrogen (Fig. 1.). Medium factors of insulation weak parts and insulation elements were theoretically and experimentally obtained and a significant unique medium factor of the apparatus were discussed with them. The studied insulation elements were coil-to-coil and current lead insulation elements. The insulation weak parts chosen mainly from the coil-to-coil insulation element were (i) uniform field gap, (ii) non-uniform field gap, (iii) triple junction defined as a contact point between a metal, a solid insulator and liquid or gaseous dielectrics and (iv) solid insulator surface. Main results are summarized as follows.

1) Uniform and non-uniform field gaps, triple junction and solid insulator surface were chosen as the insulation weak parts, and their medium factors were theoretically and experimentally clarified as a function of the gap length between electrodes and the nitrogen gas temperature.
2) The measured values medium factors were compared with the medium factor of a coil-to-coil insulation element experimentally obtained with its modeled electrode system under a given condition. It was pointed out that the medium factor of the coil-to-coil insulation element should be determined from that of its insulation weakest part, which was triple junction or solid insulator surface in our case.
3) Based on these findings, It was recommended for the safest side of the insulation design that the equivalent insulation test voltage at room temperature for the finished HTS apparatus should be determined by the maximum value of the medium factor selected from those of the insulation elements (Fig. 2.).
4) It was suggested that additional insulation distance is needed in at least one of the insulation elements for preventing discharge activities at room temperature if the ratio of the maximum medium factor to the minimum one is larger than the safety factor in the standard test voltage.

Reference

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2) Hara M., Kurihara T., Nakano R., Suehiro, J.: "Medium factors of electrical insulation systems in high temperature superconducting power apparatus with coil structure for equivalent ac withstand voltage test at room temperature", Cryogenics, Vol.45, pp.705-717 (2005)

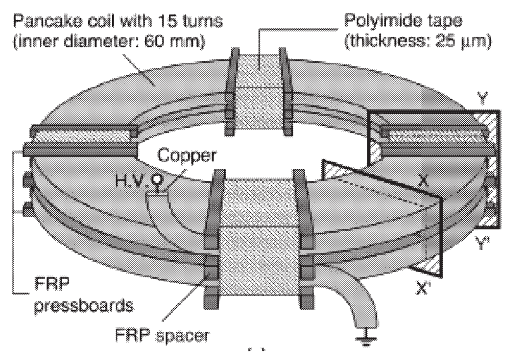

Fig. 1. Schematic diagram of modeled electrode system of coil-to-coil insulation element.

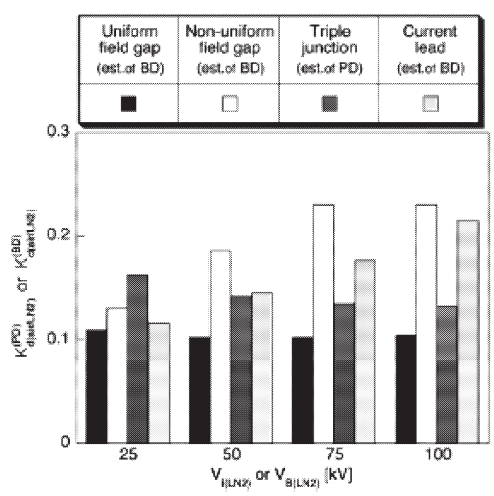

Fig. 2. Comparison between values of medium factors for various insulation systems.