§19. Study on Cryogenic Electrical Insulation for Large Scale Superconducting Coils

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The world's largest class superconducting coil is being used for the "Large-scale Helical Device". Its electrical insulation system might be exposed to considerably severe multiple stresses including cryogenic temperatures, large mechanical stresses and strong magnetic fields. It is therefore very important to study its insulation performance in order to establish the reliability of the coil. If superconductor quenches from superconducting state to normal state, the liquid coolant vaporizes very easily and turns into high-density gas at cryogenic temperature, which may reduce its withstanding voltage. Furthermore, it is very difficult to completely remove foreign substances out of the insulated space. So it is required to clarify the influence of foreign substances on the insulation performances.

A preliminary experiment was performed at liquid nitrogen temperature prior to that at liquid helium temperature. A 5-mm thick spacer made from acrylic resin was inserted between two flat electrodes. The inner diameter of the spacer wall was 15 mm. A tungsten wire of 0.1 mm in diameter, 2 mm in length was employed as a conductive foreign substance. The behavior of foreign substance in the electrode system was observed. The gap was filled with either liquid nitrogen, air or silicone oil to check the influence of viscosity on the motion of foreign substance.

Under dc voltage, the position of foreign substance could take only three conditions: the original position; standing upright at the original position; being attached to the upper electrode.

Under ac voltage, as shown in Fig. 1, the foreign substance surfaced by the electrostatic forces, then moved and rotated rapidly with the occurrence of the sound due to small electric discharge. The gravity center was traced in the interval of 1 ms. From the observation, the average speed of movement in air was as fast as 150 mm/s. In most of the cases, the breakdown took place as soon as the foreign substance finally attached to the spacer wall. The foreign substance should be trapped at suitable places before it attaches to the spacer wall.

The distance of the motion showed a tendency of becoming shorter as the viscosity of the insulation medium was high. When the frequency rose, the moving distance once reached the maximum value and then decreased. When the viscosity of the insulation medium became low, the frequency at which moving distance reached maximum value became high. It was supposed that, at high frequencies, the behavior of the foreign substance could not respond the change in instantaneous voltage because of its inertia.

It is concluded that the behavior of a foreign substance strongly depends on both frequency and viscosity. As the viscosity of liquid helium is supposed to be as low as air, the behavior of foreign substances is expected to be close to that in air. It is therefore important to survey the frequency component of the voltage waveform in both normal and abnormal conditions. Trap of the foreign substance should be considered in the process of insulation design.

Reference

1) Shmizu,Y., HIrahata,Y., Minoda,A., Kosaki,M., Hozumi,N., Satow,T. & Nagao,M., National Convention, IEEJ, 2-065 (2001).

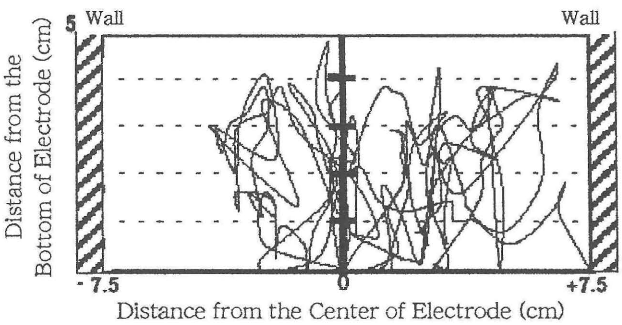

Fig. 1 An example of trace of the foreign substance. Under 60 Hz, in air.

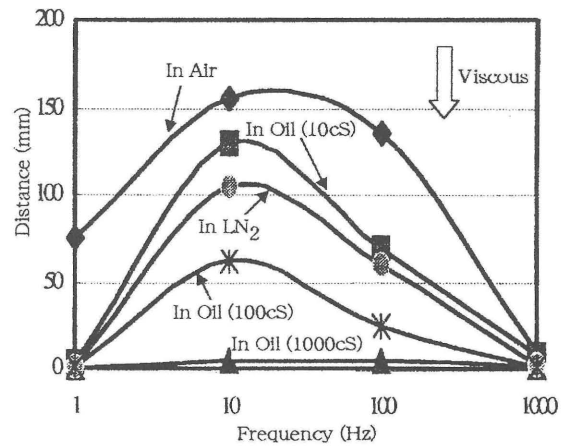

Fig. 2 Motion of a foreign substance as a function of frequency of the applied voltage.