Analysis on Creepage discharge Characteristics of according to Pressure for a 220kV SFCL

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Introduction

✓ Recently, a study on the application of a super-conducting apparatus is widely investigated according to the rapid development of industrial society due to the increasing demand of downsizing and large capacity.

✓ Solid insulation materials such as GFRP and epoxy are usually used as insulant to enhance the dielectric performance and assure the electrical stability due to their robust electrical and mechanical performance in a cryogenic condition.

✓ In this paper, dielectric experiments on the creepage discharge characteristics of glass fiber reinforced plastic (GFRP) in gaseous nitrogen (GN2) at 293 K and liquid nitrogen (LN2) at 77 K are conducted to design a high voltage superconducting apparatus with high reliability.

Experiment Conditions

✓ Experiments on the creepage discharge of GFRP in GN2 and LN2 under AC and Imp. voltages are conducted at the pressure of 0.1 to 0.5 MPa.

✓ The schematic drawing of experimental set-up is shown in Fig. 1.

✓ Fig. 2 shows the experimental electrode systems with a GFRP sheet and how to control the creepage discharge distance (CD).

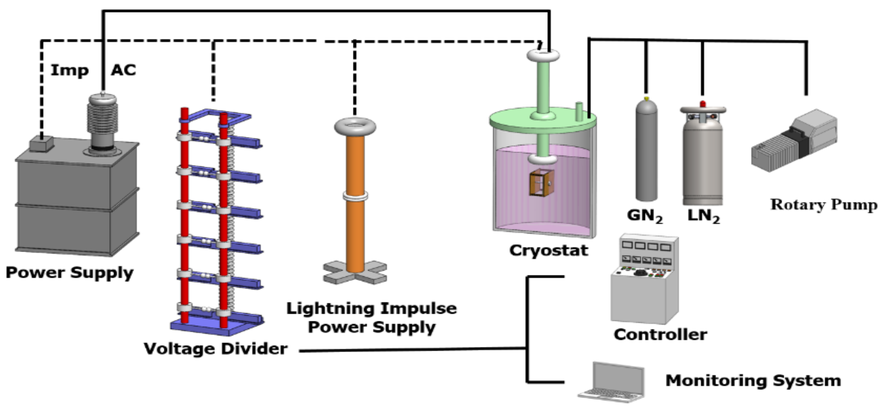

Fig. 1. Schematic of the experimental set-up.

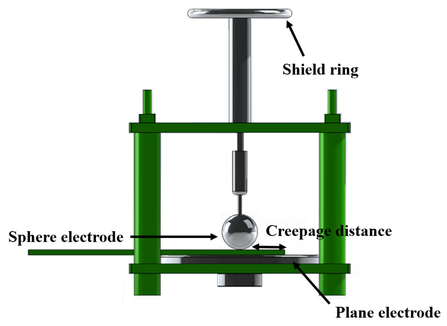

Fig. 2. Schematic drawing of electrode system.

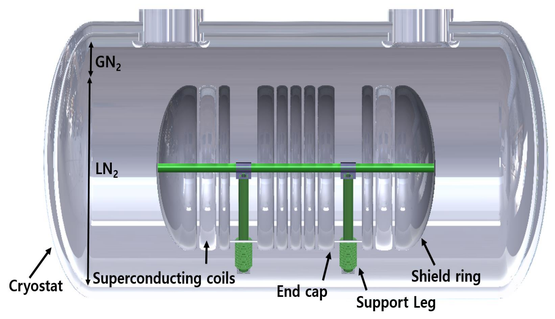

Fig. 3. Schematic of the SFCL.

✓ AC power supply with the capacity of 100 kV and Imp. power supply with the capacity of 600 kV are prepared and connected with a sphere-to-plane electrode.

✓ AC voltage is applied 7 times successively with the term of 1 kV/s . and Imp. voltage is also applied 7 times. To minimize the effect of space charge.

✓ The creepage of a GFRP sheet is cleaned with isopropyl alcohol because the dielectric characteristics of creepage discharge could be affected by impurities on the creepage of solid insulation materials.

✓ A finite element method (FEM) by COMSOL is used to analyze the electric field distribution of the creepage of a GFRP sheet.

✓ The mean electric field intensity (E_{MEAN}) and maximum electric field intensity (E_{MAX}) when input voltage is 1 kV for an FEM simulation along the discharge path are calculated.

✓ High voltage including AC and Imp. voltages is applied to a sphere electrode and a plane electrode is grounded.

✓ The mean electric field intensity at creepage discharge voltage ($E_{CD,MEAN}$) and maximum electric field intensity at creepage discharge voltage ($E_{CD,MAX}$) are calculated by (1) and (2).

✓ In this paper, electric field uniformity is represented by an electric field utilization factor (ξ) calculated by (3).

$$E_{CD,MAX} = E_{1kV,MAX} \times V_{CD} \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

$$E_{CD,MEAN} = E_{1kV,MEAN} \times V_{CD} \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

$$\xi = \frac{E_{MEAN}}{E_{MAX}} \cdots\cdots\cdots\cdots\cdots\cdots (3)$$

✓ Table 1 shows the specifications of an electrode system and experimental conditions.

Table. 1. Specifications of experiments

diameter of sphere ele ctrode (mm)	**40**	**Solid insulation**	**GFRP (t : 6mm)**
diameter of plane elect rode (mm)	200 (t : 10mm)	applied voltage	AC, Imp.
Radius of curvature (m m)	5	Surface discharge distance (mm) – LN2	10, 40, 70, 80, 90, 100, 110
Pressure (MPa)	0.1, 0.2, 0.3, 0.5		
Electrode material	Stainless steel	Surface discharge distance (mm) – GN2	20, 40, 60, 80

Table. 2. Parameters for FEM analysis

Material	Dielectric constant	Electrical conductivity (S/m)
stainless steel	1	1.1×10^{6}
GFRP	4.3	1.5×10^{-14}
GN_2	1.000580	1.1×10^{-2}
LN_2	1.45	1.1×10^{-14}

Experimental Results

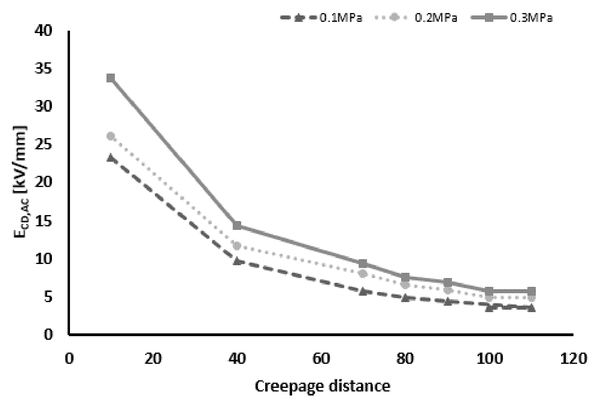

Fig. 4. Creepage discharge $E_{(CD,MAX)}$ of GFRP with respect to Creepage distance in **LN2 (@AC Voltage).**

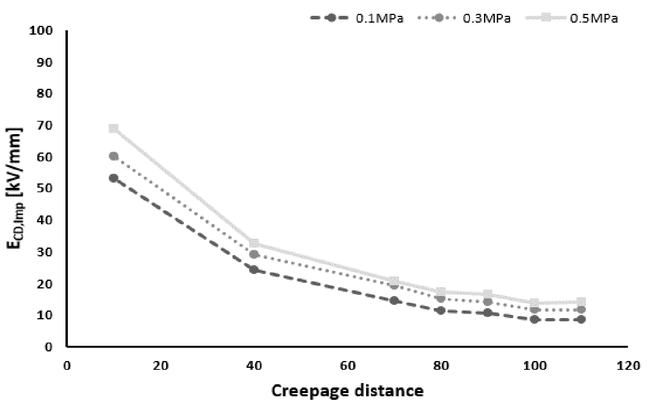

Fig. 5 Creepage discharge $E_{(CD,MAX)}$ of GFRP with respect to Creepage distance in **LN2 (@Imp. Voltage).**

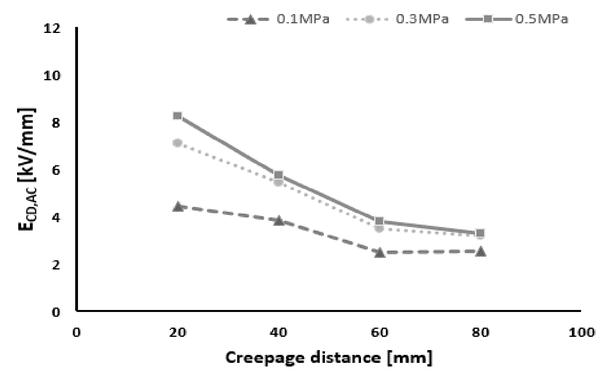

Fig. 6. Creepage discharge $E_{(CD,MEAN)}$ of GFRP with respect to Creepage distance in **GN2 (@AC Voltage).**

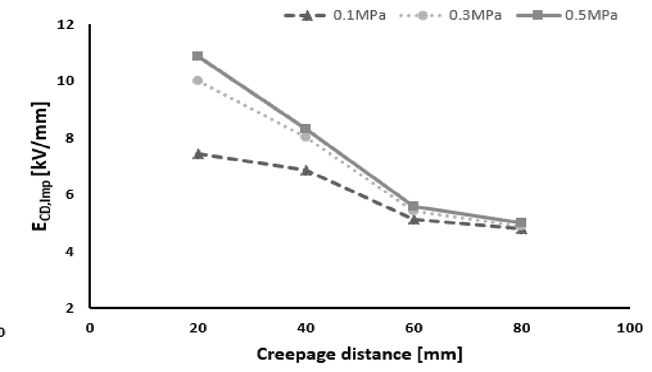

Fig. 7. Creepage discharge $E_{(CD,MEAN)}$ of GFRP with respect to Creepage distance in **GN2 (@Imp. Voltage).**

✓ experiments on the creepage discharge characteristics of a GFRP sheet in GN2 and LN2 according to discharge distance a sphere electrode by applying AC and Imp. voltages are conducted.

✓ Experimental results are shown in Fig. 4 to Fig. 7

✓ It is observed that E decreases as discharge distance increases irrelevant to the type of applied voltage.

✓ Also, It is observed that E increases as pressure increases irrelevant to the type of applied voltage.

✓ The E value of voltage variation under Imp. source is larger than that under AC source in GN_2/LN_2 with respect to discharge distance.

✓ As a result, the value increases with increasing pressure, and the value varies with creepage distance.

Discussion

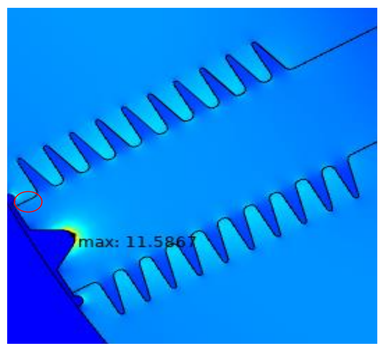

Fig. 8. Electric field distribution of simulation 20 [mm]

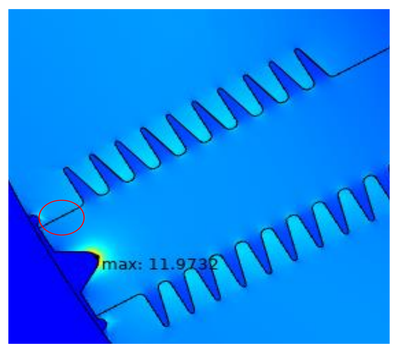

Fig. 9. Electric field distribution of simulation 40 [mm]

✓ Fig. 8 and Fig. 9 shows the distribution of support leg for which the creepage distance is 20 mm, 40mm.

✓ Simulation by COMSOL is used to analyze the electric field distribution of the creepage of support leg.

✓ Where $E_{CD,criterion}$ is the criterion of the electric field intensity at the creepage discharge (Experimental result) and $E_{CD,designed}$ represents the maximum electric field intensity of the support leg

$$SF_{(Electrical)} = E_{CD,criterion} \times E_{CD,\,designed} \cdots\cdots\cdots\cdots\cdots\cdots (4)$$

✓ Thus, the safety factor was calculated using the following equation (4).

✓ After checking the simulation program, we find that we reduced the creep-age distance from 40mm to 20mm, the safety factor in-creased from 1.2 to 2.0..

Conclusions

✓ In this paper, experiments on creepage discharge characteristics of GFRP according to pressure in GN_2 and LN_2 are conducted.

✓ As results, it is found that E value increases with increasing pressure, and the value varies with creepage distance.

✓ Based on these characteristics, We attemped to improve the stability of the support leg creepage discharge, which is a weak point of discharge of SFCL, a superconducting power apparutus. The simulation results confirmed that the safety factor is higher than before.

✓ These characteristics can be helpful for the design of superconducting devices, and We will do application next paper.

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