COUNTRY : Japan
REGISTRATION NUMBER : DLG2261

GROUP REF. : B3
PREF. SUBJECT :2
QUESTION N° : PS 2.2

Q PS2.2: Much development has taken place to reduce SF_6 impact on the environment from utility application for electrical insulating and interrupting equipment. What are likely to be the enduring initiatives to prevent SF_6 gas leaks and find a possible alternative to SF_6 for GIS applications?

Functionally Graded Material (FGM) Application for Next Generation SF_6 Alternative GIS

Introduction

The downsizing of gas-insulated switchgears (GIS) and gas-insulated transmission lines (GIL) will lead to a reduction in their cost, installation area, manufacturing energy, and use of SF_6, which is an extremely potent greenhouse gas. However, there is a limitation in insulation performance using only the conventional composite material technology. Accordingly, research and development has been conducted to downsize insulating spacers with a 30% smaller diameter using the latest functional insulating materials such as permittivity (ε) functionally graded materials (ε-FGM)[1]. Figure 1 shows the development goals of HV GIS.

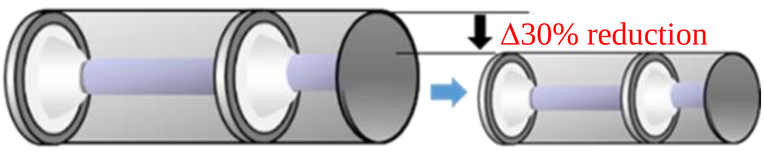


Figure 1: Development goals of HV GIS.

Details of the study

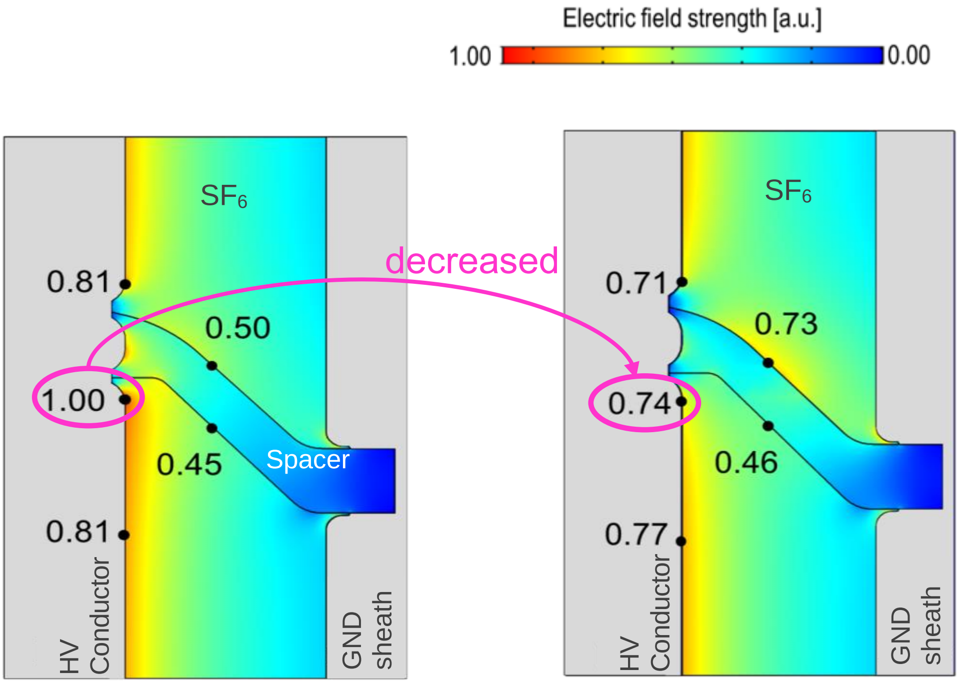
By applying the ε-FGM technique, an actual-size insulation spacer with a 30% reduction in diameter compared to that used in conventional 245 kV class GIS was achieved, and the LI FOV characteristics were verified. The permittivity distribution in solid insulating spacer was optimized by an inverse calculation technique using a newly developed electric field analysis method. Figure 2 shows the calculation results of electric field distribution. The maximum electric field stress of FGM spacer is decreased to 0.74 a.u., compared with the stress (1.0 a.u.) at the same location of the uniform spacer.

Then, a full-scale actual-size ε-FGM spacer with a distributed permittivity of 10-4 using $SrTiO_3$ and SiO_2 fillers was fabricated. Figure 3 shows the fabricated actual size cone-type spacer for 245kV class GIS.

It was experimentally verified that the FOV of the FGM spacer increased more than that of the uniform spacer with ε_r=4 under a negative standard LI voltage in SF_6 gas in the range of 0.3 to 0.6 MPa, and the average FOV was improved by 21% at 0.5 MPa-abs. Figure 4 shows the test results of LI flashover voltage for uniform and ε-FGM spacer models. In addition, a withstand voltage test of 15 times LI ±1050 kV which is a type test of the standard of 245 kV class GIS regulated in IEC 62271 was carried out with the sophisticated FGM spacer in the 30% diameter reduction 245kV GIS. As the result, the standard requirements were fully satisfied. Moreover, long term AC V-t characteristics were verified at 1.8 times the operating voltage, and it was confirmed that partial discharge and breakdown did not occur after 2000 hours, while shows the equivalent insulation life over 50 years GIS operation.

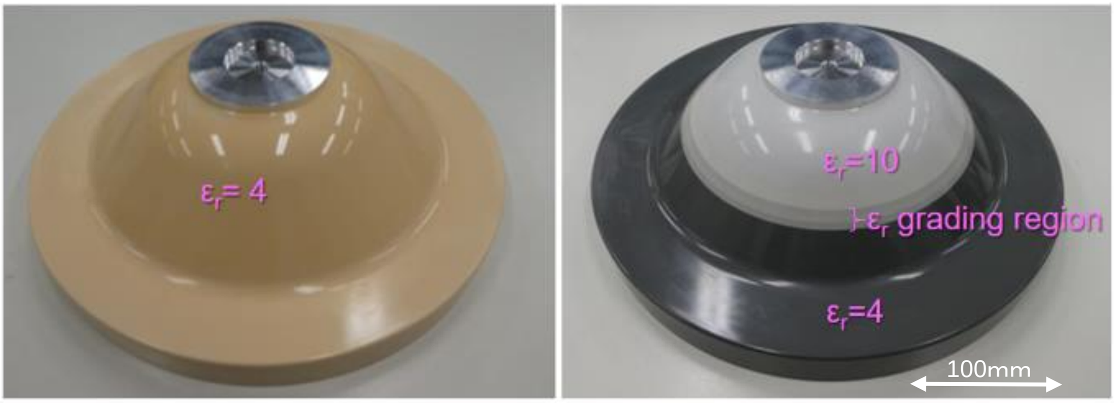
From these results by using FGM techniques, in the case of SF_6 gas, 30% downsizing of insulation spacer diameter (50% downsizing in volume) is possible, and application to gas insulation bus (GIB, GIL) can contribute to halving SF_6 gas amount.

On the other hand, in the case of SF_6 alternative gas, especially natural gas (dry air) has low insulation performance, so it is necessary to increase the diameter of insulating spacers and the filling gas pressure, and the equipment size is estimated to be 1.2-1.5 times larger, which becomes a problem, however, the FGM technology can suppress them.



(a) Uniform (b) FGM

Figure 2: Calculated electric field distribution in HV GIS.



(a) Uniform spacer (b) FGM spacer

Figure 3: Fabricated actual size (245kV class GIS) cone-type spacer.

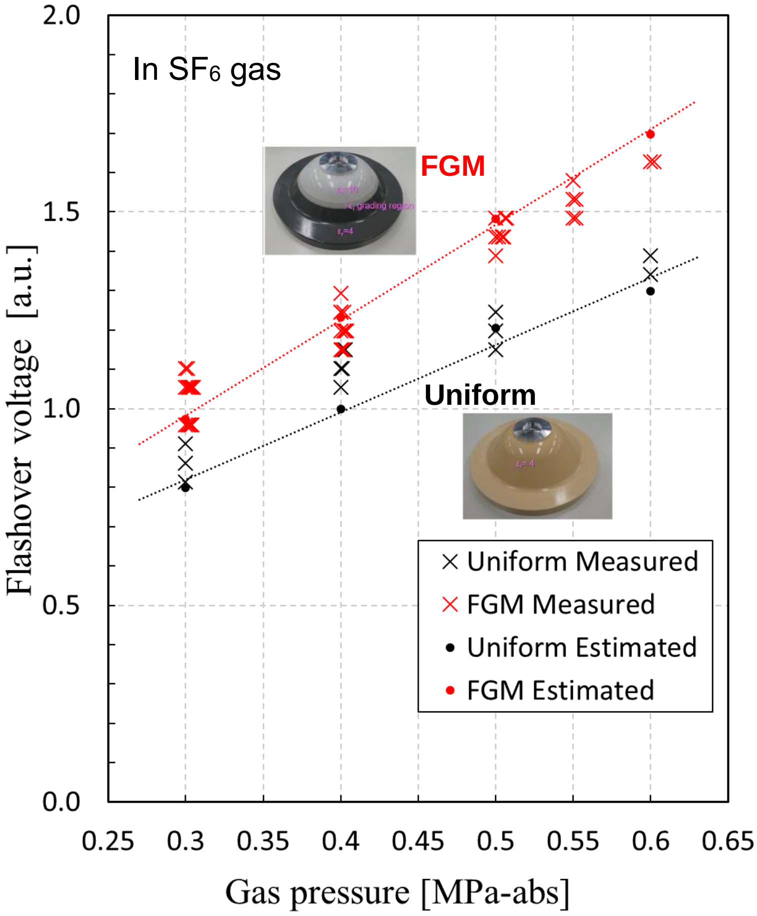


Figure 4: Test results of LI flashover voltage for uniform and ε-FGM spacer models.

Conclusion

In the case of SF6 alternative gas such as natural gas (dry air), by applying ε-FGM technology to GIS insulation spacer, it is possible to suppress the increase of insulation gap distance and gas pressure, and upsizing of equipment. In particular, it is expected to contribute to the replacement of narrow-area substations (Indoor, underground, mountain, offshore, etc.) that require the same scale. Figure 5 shows the example of a narrow GIS substation.

On the other hand, In the case of equipment using SF_6 gas, the consumption of it can be efficiently reduced by applying ε-FGM insulating spacer.

Figure 5: Example of a narrow GIS substation.

Bibliography

[1] K. Okamoto, N. Hayakawa, M. Hikita, H. Okubo, K. Kato, and N. Osawa, “Development of Sophisticated Cone-Type Insulating Spacer for 245 kV Class GIS by Functional Insulating Materials”, CIGRE Paris Session, D1-10648, 2022.