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ENHANCING THE WITHSTAND VOLTAGE CAPABILITY OF CONICAL SPACERS IN SF6 GAS INSULATED SUBSTATIONS

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Abstract

This paper reports electric potential distribution minimization in a three-phase 250 kV GIS spacer with aim to reduce the withstand voltage in the spacer. The withstand voltage around the conductor on the spacer directly depends upon how the electrical potential of conductor is distributed over the spacer volume. The three modifications of the GIS spacer structure and the material are performed to reduce electric potential distribution in the GIS spacer. First, the distance between phase conductors (d) is changed with varied ratio of 0.8, 1.0, and 1.2 times of original distance (d). The second parameter changed for modification in the spacer form is contact angle. The contact angle (θ) refers to the angle between the spacer-HV electrode side and the spacer-grounded electrode side. This angle is varied from 65°, 45°, and 35°. The last parameter changed for modification in the spacer form is high permittivity material usage which reduces the electrical potential stress in the spacer.

***Index Terms* – Potential distribution, contact angle, Gas Insulated Substations.**

Introduction

It is important to achieve minimum voltage stress in the insulation of gas insulated substations to prevent the insulation failure. Each part of GIS should be designed to achieve minimum potential distribution over the insulation. In-order to minimize the potential distribution in GIS, some modifications on the spacer may be performed, such as on its shape, spacer material which is represented by relative permittivity (ε_R), distance between phase conductors, and phase conductor configuration. By changing these parameters, it was proven that the potential distribution in GIS could be reduced. In this paper the modification of spacer shape, size, and configuration is discussed to achieve minimum potential distribution in spacer volume which ultimately leads to reduced withstand voltage capacity for spacer insulation.

Simulation Method

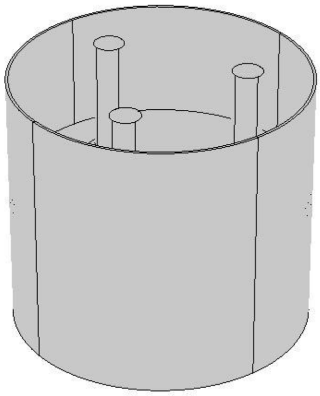
There are two steps of simulation method conducted in this research. The first step is modelling the three-phase 145 kV GIS including the spacer. The second step is the modification of spacer in-order to minimize the electric potential distribution, specifically to reduce around the conductors.

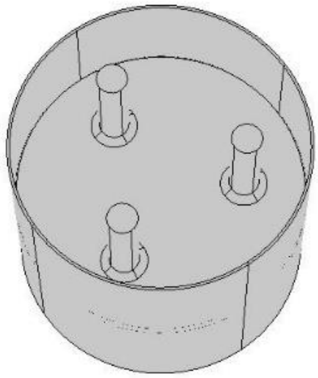
Three-phase 250 kV GIS Components Modelling

A three-phase GIS in 3D form is used for modelling in this research, which consists of GIS tank (enclosure), phase conductor, and spacer with specification as written in Table 1.

Table-1

Components	Parameters	Value
GIS	Length	1m
	Diameter	0.56m
	Thickness	0.01m
	Material	Aluminum (ε_R=1.6)
Phase conductor	Length	1m
	Diameter	0.058m
	Material	Aluminum (ε_R=1.6)
	Coordinates	Phase R (0.277, -0.16, 0) Phase Y (0, 0.32, 0) Phase B (-0.277, -0.16, 0) Equilateral triangle configuration
2310313_526344_970_975Spacer	Material	Epoxy resin
Insulation Gas	Material	SF6 Gas





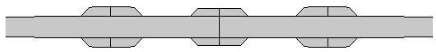
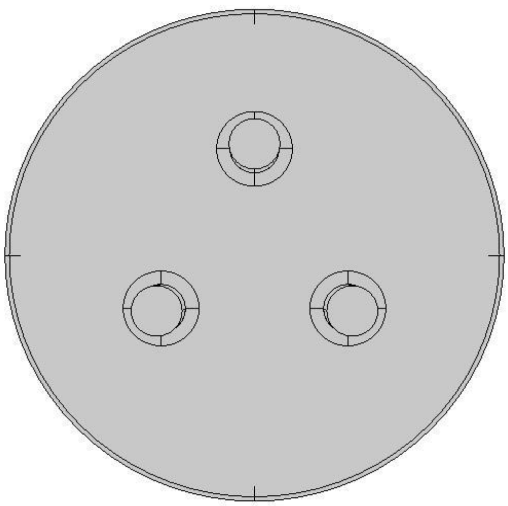


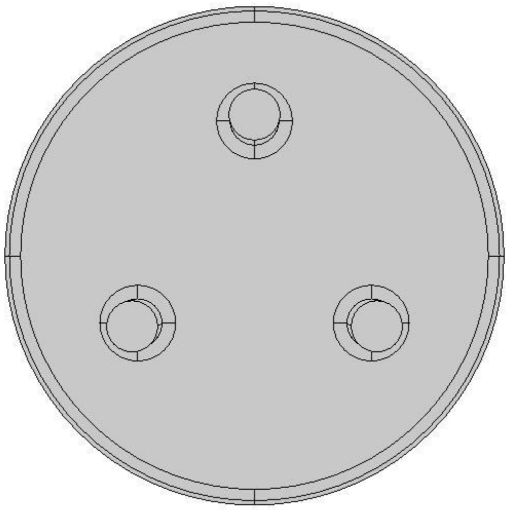
Fig-1-Front view of GIS, 2-Top view of GIS, 3-Front view of conical spacer

Spacer modifications

Some modifications on the spacer are performed, such as on its shape, spacer material which is represented by relative permittivity (ε_R), distance between phase conductors, and spacer cone configuration.

By changing those parameters, it was assumed that the voltage distribution in GIS could be reduced. Before the modifications performed on the spacer, the voltage distribution around the spacer is examined, this from here after will be called as the unmodified spacer condition. The three modifications performed on the spacer are related to the spacer form. First, the distance between phase conductors (d) is changed with varied ratio of 0.8, 1.0, and 1.2 times of original distance. The original distance between phase conductors is 554 mm and obeys the equilateral configuration of phase conductors.





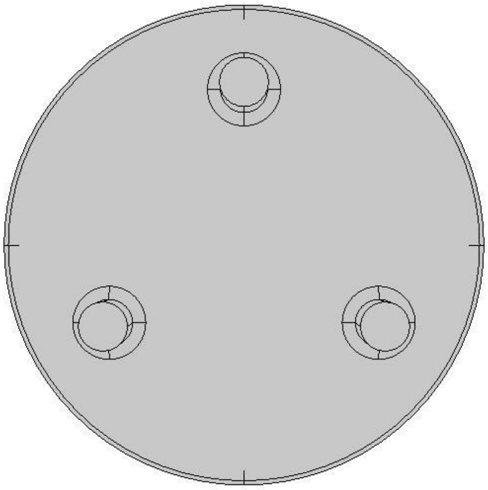


Fig-4,5,6-variation of distance between conductors(d) with factor of 0.8,1.0,1.2

The second parameter changed for modification in the spacer form is contact angle. The contact angle (θ) refers to the angle between the spacer-HV electrode side and the spacer grounded electrode side. This angle is made varied from 65°, 45°, and 30°

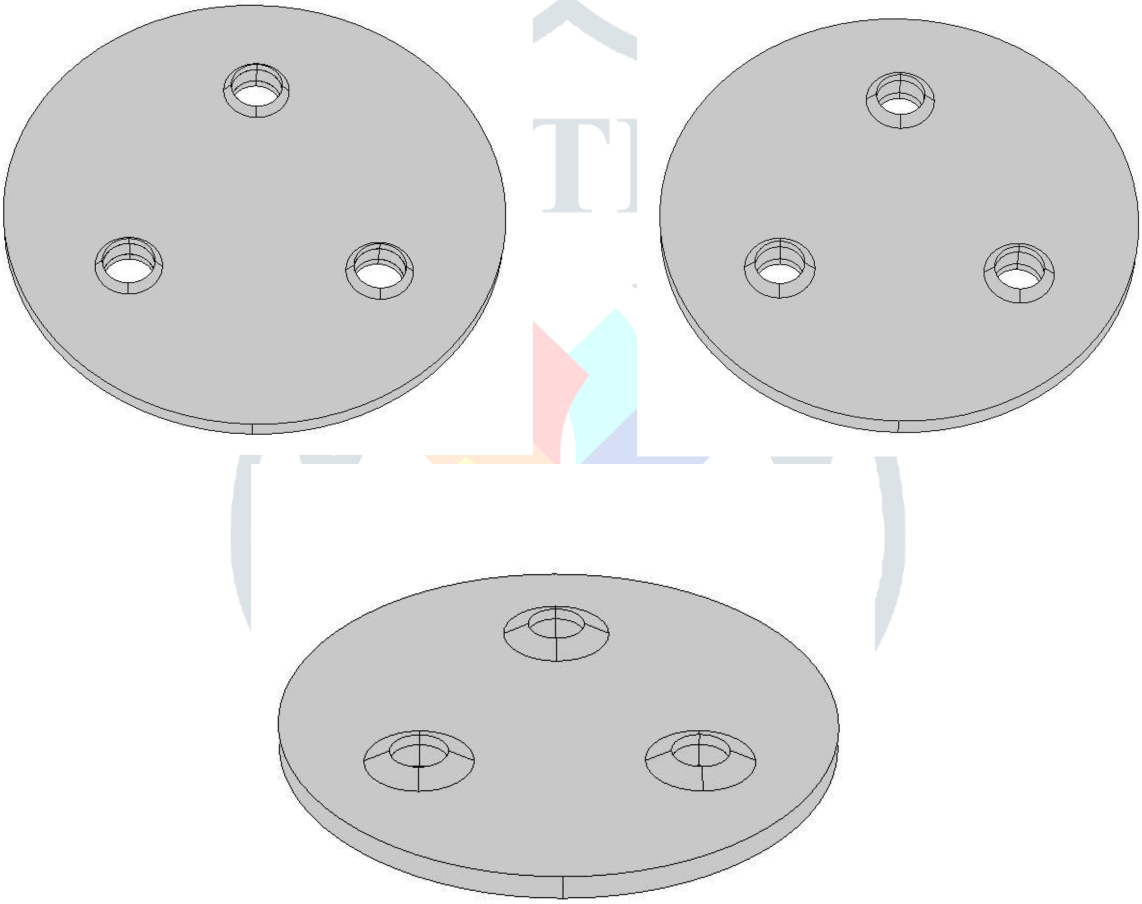


Fig-7,8,9-variation of conical angles of spacer as 35°,45°,65° respectively

Simulation results

1.SPACER MODIFICATION BY VARIED DISTANCE BETWEEN CONDUCTORS

The simulation results on spacer potential distribution due to modification on the distance between phase conductors is shown in Figure 10.

The potential distribution obtained at the smallest distance between phase conductors (0.8d) is more. Then, the potential distribution along the spacer surface decreases along with the increase of distance between phase conductors from 0.8d to 1.2d. From the below graph, thus it can be seen that lowest potential distribution is obtained at 1.2d.

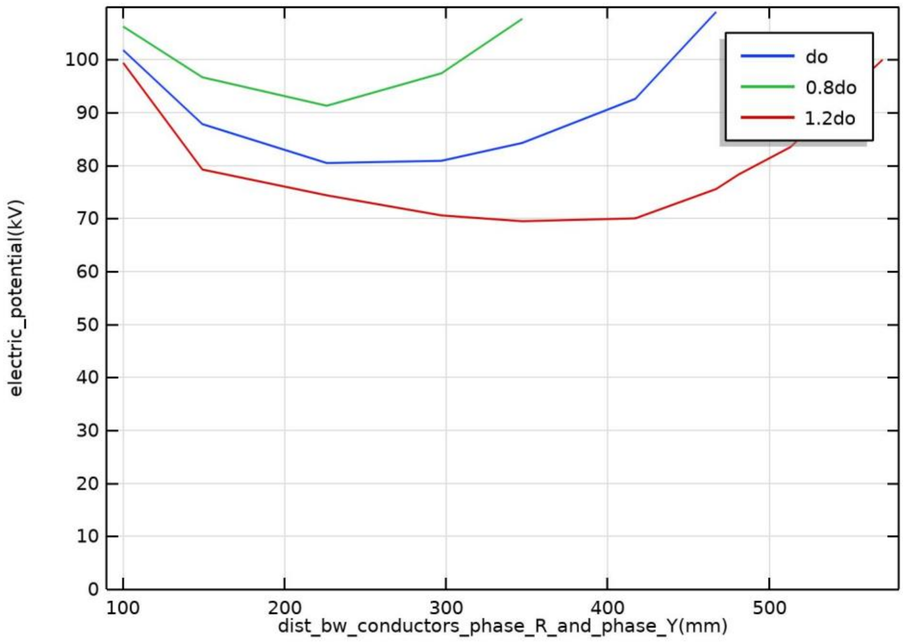


Fig-10

Thus, the distance between phase conductors would affect more to the potential distribution rather than the distance between phase conductors to enclosure.

2.SPACER MODIFICATION BY CHANGING RELATIVE PERMITIVITY OF SPACER MATERIAL

The simulation results on spacer potential distribution due to modification in permittivity of spacer material is shown in Figure 11.

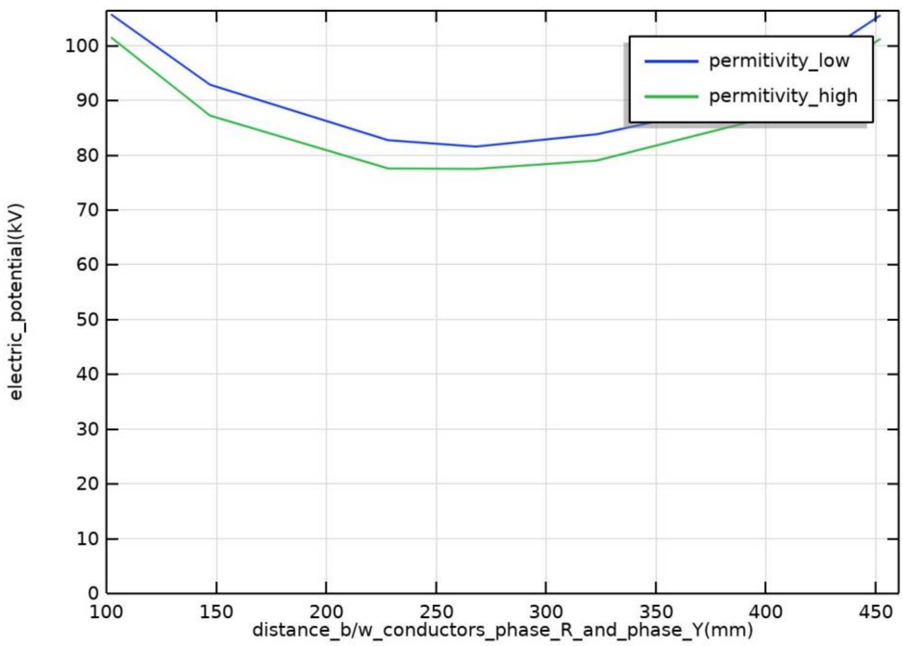


Fig-11

The simulation results of potential distribution between the phase conductors is high for low relative permittivity material in which epoxy resin of relative permittivity ε_R=4.2 and the capability of voltage distribution in improved in high relative permittivity material of epoxy resin ε_R=8.4.

3. SPACER MODIFICATION BY CHANGING SPACER GEOMETRY OPTIMIZATION

The last modification on spacer that is conducted is varying the contact angle (Θ) of the spacer. The 2D assumption of contact angle between the high voltage conductor and grounded enclosure is shown in Figure 12. The simulation results by varying contact angle are shown in Figure 13.

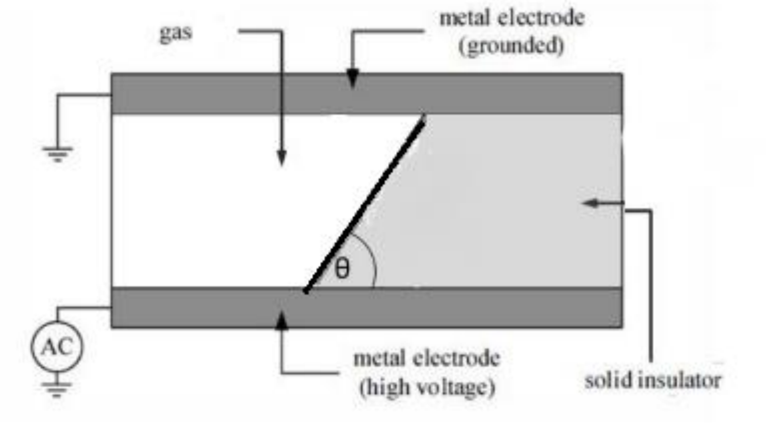


Fig-12-Contact angle

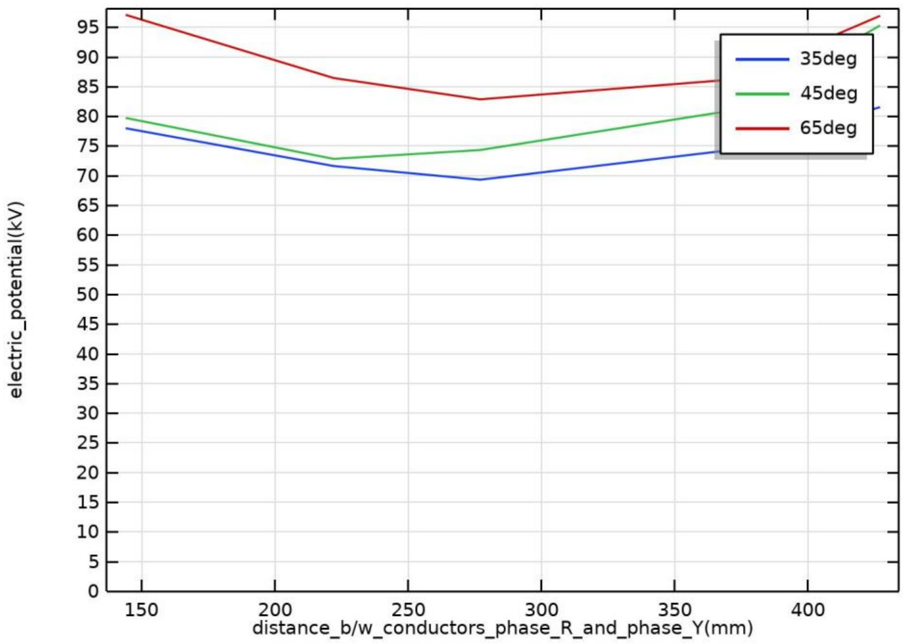


Fig13

Based on the simulation result of 3D spacer model with optimized contact angle, the lowest potential distribution is obtained at contact angle of 35°. It is also understood that the potential distribution around the spacer between the phase conductors decreases as the contact angle decreases. It is the reason the contact angle of 35° has given the lowest voltage distribution compared to the other variations of contact angle.

CONCLUSIONS

In this research, it has been successfully proven that some modifications in the spacer form can reduce potential distribution particularly around the phase conductors, thus reduces withstand voltage of spacer insulation in a 250 kV GIS spacer. The conclusions are as follows.

1. The initial form or the unmodified 250 kV GIS spacer model has compared with the modified models of conical spacers.
2. The modifications performed to the spacer in simulation software consist of modifications on relative permittivity, spacer distance and configuration between phase conductors, and contact angle.
3. Modification performed by controlling the phase conductor configuration as equilateral triangle configuration and distance between the phase conductors is 1.2 times of the original distance of the unmodified spacer gives better voltage distribution capability.
4. Modification performed by increasing the relative permittivity of the spacer material gives improved voltage distribution capability.
5. Last Modification is performed by controlling the contact angle of cones of spacer as 35° gives better voltage distribution capability.

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