Performance of 1-ϕ GIS with and without dielectric coating

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Abstract. In Gas Insulated Substations (GIS), a free conducting particle can approximate any shape. If the conductor surface is not smooth and rough, then dielectric strength will be lost. So, to regain the dielectric strength, which was lost, the conductor inner surface is coated with a dielectric material of epoxy resin for which the dielectric strength can be regained. In this paper, work of simulation is done for voltage class 132kV, 145kV, 220KV and 245KV in a 1-ϕ GIB for Al & Cu particles and peak radial movement was found. All the simulation analysis was carried out and results are shown in detail.

Keywords. Gas Insulated Bus duct (GIB), Gas Insulated substation(GIS), Breakdown (B.D), Particle movement, Dielectric coating

1. Introduction

Across the globe, Gas Insulated Substation (GIS) is widely preferred as it offers excellent benefits compared to Air Insulated Substation (AIS). The main parameters for popularity of GIS is its safety, problems of land availability and pollution aspects. Hence, there is necessity of shifting from the AIS to GIS. It was known from the studies that almost 30% failures are caused because of contamination of particles which is by defects of manufacturing or due to transportation [1-2]. There are so many merits with dielectric coating in GIB. If the inner surface is rough, then chances of failure of insulation is more as it deteriorates the dielectric strength. But with coating, the surface becomes smooth and chances of insulation failure is less, and electrical strength increases and lift-off field also increases. At the same time, the charge acquired by the particle also reduces.

In this paper, the free conducting particle radial peak movement was found in 1-ϕ GIB for with & without dielectric coating.
2. Mathematical modelling
Here, a filamentary particle of wire like is assumed to be at rest as shown on the surface inner of the outer enclosure, and lift-off field exists, provided the particles possess sufficient charge under electric field [3]. All the given equations are based on Felici et.al[1]

![Schematic Diagram of a typical 1-Ø GIB.](image)

**Figure 1.** Schematic Diagram of a typical 1-Ø GIB.

The motion equation of the particle is shown as differential equation of second order given below [4-6]:

\[
m_y(t) = \left[ \pi \varepsilon_0 l^2 E(t_0) \times \frac{V \sin \alpha}{\ln(2r/t) - l} \right] - mg \\
- \dot{y}(t) r \pi r \left[ 6 \mu K_M(y) + 2.656 \left[ \mu_p l y(t) \right]^{0.5} \right]
\]

3. Motion of particle simulation
The Particle charging mechanism [4] for dielectric coating is shown in figure2.

![Mechanism of charging of a free particle on a coating of dielectric.](image)

**Figure 2.** Mechanism of charging of a free particle on a coating of dielectric.

The lift-off field equation in case of dielectric coating is given as:

\[
E_{LO} = \left[ \frac{mg}{K \omega B \varphi} \ln \frac{r_0}{r_i} \right]^{0.5} \left[ R \left( 1 + \frac{C_s}{C_g} \right)^2 + \frac{1}{R^2 \omega^2 C_g^2} \right]^{0.5} = K \left[ 1 + \frac{C_s}{C_g} \right]^2 + \frac{1}{R^2 \omega^2 C_g^2} \left( \frac{E_0}{S} \right)^{0.5}
\]
4. Result analysis
All the results of simulation shown are achieved for \( l=10\text{mm}, \ r=0.3\text{mm} \) for voltage levels 132KV, 145KV, 220KV and 245KV with calculation of field for with and without dielectric coatings and are compared as depicted in Table 1 for 1-\( \Phi \) GIB using advanced C language program.

It can be inferred from the results that without coating, particularly for Al particles, the mobility is higher than Cu particles due to lighter mass. However, with dielectric coating, the mobility of the particle greatly reduces as against without coating, both for Al and Cu particles [4-10]. This is because of the fact that coating material inhibits the mobility of the particle and it raises the breakdown voltage. There are various types of coating materials namely epoxy, RT 481, GK 115, Al2O3 etc. But in this work, epoxy resin coating of light shade 100micron thickness is used. For voltages 220KV and 245KV as depicted in table 1, no mobility of the particle was observed for without coating as the particle crosses the inter electrode gap. Figs 3 to 10 show the Peak radial movements for Al & Cu particles with coating of dielectric epoxy resin of 100micron thickness [11-21]. Figures 11 to 16 show the Peak radial movements for Al & Cu particles without coating.

| Sl. No. | Voltage (kV) | Particle type | Peak Radial Movement with Coating(mm) | Peak Radial Movement without Coating(mm) |
|--------|--------------|---------------|--------------------------------------|----------------------------------------|
| 1      | 132          | Al            | 1.24                                 | 47.94                                  |
|        |              | Cu            | 0.299                                | 15.97                                  |
| 2      | 145          | Al            | 1.6                                  | 58.715                                 |
|        |              | Cu            | 0.391                                | 17.507                                 |
| 3      | 220          | Al            | 2.62                                 | C.G                                    |
|        |              | Cu            | 0.922                                | 26.223                                 |
| 4      | 245          | Al            | 3.52                                 | C.G                                    |
|        |              | Cu            | 1.392                                | 48.340                                 |

4.1. C.G-Crossing the electrode gap

With coating:

![Figure 3. Mobility pattern for Al particle for 132KV](image-url)
Figure 4. Mobility pattern for Cu particle for 132 KV.

Figure 5. Mobility pattern for Al particle for 145 kV.

Figure 6. Mobility pattern for Cu particle for 145 kV.

Figure 7. Mobility pattern for Al particle for 220kV.
4.2. **Without coating:**

Figure 8. Mobility pattern for Cu particle for 220 kV.

Figure 9. Mobility pattern for Al particle for 245 kV.

Figure 10. Mobility pattern for Cu particle for 245 kV.
Figure 11. Mobility pattern for Al particle for 132 KV.

Figure 12. Mobility pattern for Cu particle for 132 KV.

Figure 13. Mobility pattern for Al particle for 145 kV.

Figure 14. Mobility pattern for Cu particle for 145 kV.
5. Conclusion
Peak movement in radial direction was found at the particle locations for with and without dielectric coatings and compared and a mathematical model was developed. An advanced C program language is used for simulation. It is noticed that Al particles have higher movement than Cu particles both for with and without coatings. Due to lighter in weight, it is also observed that particles of Al are highly affected by the voltage than copper particles. The mobility of the particle is greatly reduced with dielectric coating as against without dielectric coating due to reduction in the charge possessed by the particle. All the analysis of results are done for 132KV, 145KV, 220KV and 245KV and presented.

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6. References
[1] Felici N J 1966 Forces et charges de petits objects en contact avec une electrode affectee d’un champ electriqueRevue generale de l’ electricite 1145-1160
[2] Malik NazarH 1989 A Review of the charge simulation method and its applications IEEE Trans. Electr. Insul. 243-20
[3] Singer H, Steinbigler H and Weiss P 1974 A charge simulation method for the calculation of high voltage fields IEEE Power Engineering Society 5 1-8
[4] Subrahmanyam KBVSRand Deshmukh R 2019 Effect of coating of dielectric in a 3-phase GIB with particle movement International Journal of Engineering and Advanced Technology 8(6) 3534-38
[5] Deshmukh R, Gopikrishna N, Kumar B S, Babu D Rand Shekar P V R 2019 Design and development of a prototype-electronic langur International Journal of Recent Technology and Engineering 8 (1C2) 239-43
[6] Subrahmanyam KBVSR and Amarnath J 2012 Metallic particle movement in GIB with dielectric coated enclosure using CSMNational Conference on Recent Trends in Power Systems and Power Electronics organized by BVC Engg. College OdalarevuAmalapuram1-4

[7] Sivakumar M, Ramakrishna M S, Subrahmanyam KBVSR and Prabhandini V 2017 Modelorder reduction of higher order continuous time systems using intelligent search evolutionary algorithmInternational Conference on Recent Trends in Electricaland Electronics and Computing Technologies 70-76

[8] Chinthamalla R, Karampuri R, Jain S, Sanjeevi Kumar P and Blaabjerg F 2018 Dual solar photovoltaic fed three-phase open-end winding induction motor drive for water pumping system application Electric Power Components and Systems46(16) 1896-1911

[9] Thummapal D, Kothari S and Thirumalai M 2019 Emerging technologies in high voltage gas insulated switchgear-clean air GIS and NCITInternational Conference on High Voltage Engineering and Advanced Technology (ICHVET) doi: 10.1109/ICHVET.2019.8724126

[10] Baofeng Pan, Guoming Wang, Huimin Shi, Jiahua, Shen Hong-Keun Ji and Gyung-Suk Kil 2020 Green gas for grid as an eco-friendly alternative insulation gas to SF6: A ReviewApplied Sciences journal doi:10.3390/app10072526

[11] Shiva C K, Vedik Band Kumar R 2019 Integration of distributed power sources to hydro-hydropower system subjected to load frequency stabilization International Journal of Engineering and Advanced Technology8(2) 128-132

[12] Subrahmanyam KBVSR and Amarnath J 2011 Dynamics of metallic particle contamination in gas insulated substation (GIS)International Journal of Electrical and Electronics Engg. 1(2) 105-110

[13] Basetti, V, Chandel A K and Subramanyam K B V S R 2018 Power system static state estimation using JADE-adaptive differential evolution technique Soft Computing22(21) 7157-76

[14] Sudhakar AVV and Karri C 2017 Bio inspired algorithms in power system operation: A ReviewProceedings International Conference on Recent Trends in Electrical Electronics and Computing Technologies3 1-8

[15] Mudi J, Shiva C K, Vedik B and Mukherjee V 2020 Frequency stabilization of solar thermal-photovoltaic hybrid renewable power generation using energy storage devices Iran J Sci Technol Trans Electr Eng. https://doi.org/10.1007/s40998-020-00374

[16] Vedik B, Shiva C K and Harish P 2020 Reverse harmonic load flow analysis using an evolutionary technique SN Appl. Sci.21584. https://doi.org/10.1007/s42452-020-03408-4

[17] Vedik B, Ritesh K, Deshmukh R and Shiva C K 2020 Renewable energy based load frequency stabilization of interconnected power systems using quasi-oppositional dragonfly algorithm J Control AutomElectr Syst. https://doi.org/10.1007/s40313-020-00643-3

[18] Vedik B, Naveen P and Shiva C K 2020 A novel disruption based symbiotic organisms search to solve economic dispatch Evol. Intel. https://doi.org/10.1007/s12065-020-00506-5

[19] Seena Naik K, and Sudarshan E 2019 Smart healthcare monitoring system using raspberry Pi on IoT platform ARPN Journal of Engineering and Applied Sciences14(4) 872-876

[20] Mahender K, Ramesh KSand Kumar TA 2017 An efficient ofdm system with reduced papr for combating multipath fading Journal of Advanced Research in Dynamical and Control Systems9(14) 1939-48

[21] Mahender K, Kumar TA and Ramesh KS 2017 Performance study of OFDM over multipath fading channels for next wireless communications International Journal of Applied Engineering Research12(20) 10205-10