Particle movement pattern in a 1-Ø GIB under abnormal conditions

KBVSR. Subrahmanyam¹, K. Sravan Kumar², A. Deshmukh³ and P. Joshi³

¹Department of Electrical and Electronics Engineering, DNR College of Engineering and Technology, Bhimavaram, Andhra Pradesh, India, Pin:534202
²Department of Electrical and Electronics Engineering, Sumathi Reddy Institute of Technology for Women, Warangal, Telangana, India, Pin: 506371
³Department of Electronics and communications Engineering, KLS Gogte Institute of Technology, Belagavi, Karnataka, India, Pin-590008

Email:libra_22@rediffmail.com

Abstract. Power system comprises of various over voltages which are transient in nature namely lightning and switching phenomenon under abnormal conditions which cause flashover in Gas Insulated Bus-duct (GIB) if not protected properly. So, there is a necessity for GIS to have withstanding capability of lightning and switching. Otherwise they may cause shut down of the system. In this work, 1050 kV Lightning Impulse and 750 kV Switching Impulse is superimposed on normal frequency voltage class of 100 kV, 132 kV and 145kV and are given to 1-ØGIB for finding peak radial movement for Al and Cu particles. The movement patterns for both lightning and switching over voltages are compared. All the simulation results are shown in this paper

Keywords. Gas Insulated Bus duct(GIB), Gas Insulated Substation (GIS), Breakdown (B.D), Air insulated substation(AIS), Particle Movement, Lightning, Switching.

1. Introduction
Today, Gas Insulated Substations (GIS) are widely used because of their excellent aesthetic and technical merits to Air Insulated Substation (AIS). GIS is more reliable and safer than AIS in many aspects. One of the important parameters affecting the system of GIS is the contamination of the metallic particle[1]. They may approximate any shape. Over voltages which are transient in nature are two types namely lightning and switching phenomenon. Switching phenomenon is internal to the system. Lightning phenomenon is external to the system and depends on climatic conditions.

The gas that is widely used in GIS is the compressed SF₆gas as it possesses wonderful dielectric strength and properties of arc quenching. In this paper, particle radial peak movement was found in 1-Ø GIB for both lightning and switching phenomenon superimposed on normal frequency voltages and are compared. Lightning and switching over voltages are shown as a double exponential wave shape [12-19].
2. Mathematical modelling

Here, particle is assumed to be wire like in nature and its position is assumed to be on the outer enclosure surface, and the particle may move upwards from rest provided it possess lift-off field and at the same time, acquires charge in the field presence[3]. All the equations utilized are based on Feliciet.al[2]

![Figure 1.1-Ô GIB Schematic Diagram.](image)

The motion of the particle equation finally is shown as[9]:

\[
m\ddot{y}(t) = \left[ \frac{\pi \epsilon_0 L E(t_0)}{\ln(\frac{2L}{r}) - 1} \times \frac{V \sin \omega t}{[r_0 - y(t)] \ln \frac{r_0}{r}} \right] - mg
\]

\[
- \dot{y}(t) \pi r \left( 6 \mu K_d (\dot{y}) + 2.656 [\mu \rho_n 1 \dot{y}(t)]^{0.5} \right)
\]

2.1. Voltages of Impulse in nature

2.1.1. 250/2500 µsec switching impulse

\[
V = V_0 \times Y_0(e^{\alpha t} - e^{\beta t})
\]

Where \( V_0 = 750 \) KV

\( Y_0 = 2.225, \alpha = 0.3585 \times 10^3, \beta = 0.7429 \times 10^4 \)

2.1.2. 1050KV, 1.2/50 µsec Lighting impulse

Where \( V_0 = 1050KV \) \( Y_0 = 1.04, \alpha = 0.1477 \times 10^5, \beta = 0.1933 \times 10^7 \)

\[
V = V_0 \times Y_0(e^{- \alpha t} - e^{- \beta t})
\]

3. Result analysis

All the results are tabulated in Table 1 and Peak radial particle movement was found for particle length of 12mm, radius of 0.3mm are obtained with for voltage class 100KV, 132KV and 145KV. With an advanced C language program, simulation is done [7].
It is observed from the table and graphs that as the voltage level increases both for lightning and switching impulse, particles of Al show greater movement in the radial direction compared to Cu particles due to lighter mass[6]. Also, with the comparison of lightning and switching over voltages as depicted in table 1, the particle movement is higher for lightning impulse as against switching impulse over voltages. This is due to the magnitude high for lightning impulse of 1050 kV, 1.2/50µsec and this can cause severe flashover and the system get shutdown.

This problem can be eliminated with coating of dielectric of suitable thickness of the inner surface of the outer enclosure of the GIB[4-5]. Also, with this, the system integrity will improve, the performance of the dielectric will be good and the breakdown risk will be reduced. Figures 2 to 9 show the Peak radial movements of lightning and switching impulse over voltages superimposed for both particles of Al &Cu.

| Sl. No. | Voltage (kV) | Particle type | Peak Radial Movement with Lightning Impulse(mm) | Peak Radial Movement with switching Impulse(mm) |
|--------|--------------|---------------|-----------------------------------------------|-----------------------------------------------|
| 1      | 100          | Al            | 66.82                                         | 61.8                                          |
|        |              | Cu            | 22.08                                         | 18.87                                         |
| 2      | 132          | Al            | 68.23                                         | 63.26                                         |
|        |              | Cu            | 26.45                                         | 20.04                                         |
| 3      | 145          | Al            | 69.03                                         | 68.34                                         |
|        |              | Cu            | 38.26                                         | 33.24                                         |

**Figure 2.** Particle mobility for 132KV of Al for lightning impulse.
Figure 3. Particle mobility for 145KV of Al for lightning impulse.

Figure 4. Particle mobility for 132KV of Cu for lightning impulse.

Figure 5. Particle mobility for 145KV of Cu for lightning impulse.
Figure 6. Particle mobility for 132KV of Al for Switching impulse.

Figure 7. Particle mobility for 145KV of Al for Switching impulse

Figure 8. Particle mobility for 132KV of Cu for Switching impulse.
4. Conclusion

Particle trajectory was found using a Mathematical model along with the peak movement in the direction of radial in nature. An advanced C program language is used for simulation. It can be inferred that especially particles of Al are more affected and influenced with increase of voltage levels have higher movement than Cu particles with lightning impulse than switching impulse. Due to lighter in weight, it is also observed that particles of Al are highly effected by the voltage than copper particles. The results of simulation is done for 100KV, 132KV, 145KV, and are analysed and presented.

Acknowledgements

Authors would like to thank Mr. Ritesh Kumar, Assistant Professor, EED, S R Engineering College, for helping all the way to prepare the manuscript and technical ideas provided.

5. References

[1] Malik N H 1989 A review of charge simulation method and its applications IEEE Transactions on Electrical Insulation24 3-19
[2] N J Felici 1966 Forces et charges de petits objects en contact avec une electrode affectee d’un champ electrique Revue generale de l’electricite 1145-60.
[3] Singer H, Steinbigler H, and Weiss P 1974 A chargesimulation method for the calculation of high voltage fields IEEE Transactions on Power Apparatus and Systems 93 1660-68
[4] Nagesh Kumar G V, Amarnath J and Singh B P 2008 Behavior of metallic particles in a single-phase gas insulated system with dielectric coated electrodes International Conference on Condition Monitoring and Diagnosis Beijing China 377-80
[5] Rama Rao Narapareddy and Amarnath J 2012 Effect of image charges and dielectric coating on particle trajectory in a 3-phase gas insulated bus duct using charge simulation method International Review on Modeling and Simulation 5 1541-1549
[6] Subrahmanym KBVSRand DeshmukhRam 2019 Effect of coating of dielectric in a 3-phase GIB with particle movement International Journal of Engineering and Advanced Technology 8 3534-38
[7] Subrahmanym KBVSR and Amarnath J 2014 Effect of impulse voltage on particle movement in a GIB using charge simulation method (CSM) National Conference on Gas insulated Substations(GIS) organized by Central Board of Irrigation & Power (CBIP) and CIGRE New Delhi 52-57
[8] 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.

[9] SubrahmanyamKBVSR and Amarnath J 2011Dynamics of metallic particle contamination in gas insulated substation (GIS)International Journal of Electrical and ElectronicsEngg. I(II) 105-110.

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

[11] Sudhakar, AVV and Karri C 2017 Bio inspired algorithms in power system operation: A Review, Proceedings 2017International Conference on Recent Trends in Electrical, Electronics and Computing Technologies3 1-5.

[12] 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.

[13] 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.

[14] 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.

[15] 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.

[16] Kumar R, Sahu B, Shiva C K and Rajender B2020 A control topology for frequency regulation capability in a grid integrated PV systemArchives of Electrical Engineering69(2)389–401.

[17] Mahender K, Anil Kumar T and Ramesh KS 2017 SER and BER performance analysis of digital modulation schemes over multipath fading channels Journal of Advanced Research in Dynamical and Control Systems9(14) 1939-48.

[18] 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

[19] Mahender K, Ramesh KS and 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.