THE STUDY ON BREAKDOWN CHARACTERISTICS AND APPLICATION WAY OF DRY AIR IN 362 KV AND 170 KV GIB

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Abstract: we studied the electrical breakdown characteristics through AC withstand voltage test on GIB of 362 kV and 170 kV GIS, which were filled with dry air instead of SF_6 gas. The AC withstand voltage test was applied to the KEPCO's standard GIB with dry air and magnitudes of breakdown voltage of dry air were compared with that of SF_6 gas. From the experimental results, the standard formula of AC withstand voltage test of dry air was derived. Using the standard formula, we also confirmed the on-site usage of dry air by factory routine test. Also, we considered its application way. In this paper, we would like to explain about electrical test results of dry air and its application way in our GIB.

1 INTRODUCTION

Because the SF_6 gas has a superior dielectric strength, excellent arc extinguishing capacity and stable thermal/chemical characteristics, it's widely used as an insulation material of GIS(Gas Insulated Switchgear). But the SF_6 gas is easy to be liquefy by low temperature and high pressure. Its dielectric strength becomes lower at an nonuniform electric field and its price is expensive. Furthermore, its global warming potential(GWP) is 23,900 times higher than CO_2 gas and the influence on global warming lasts for long time owing to its chemical stability. So SF_6 gas was named as one of the the main greenhouse gases in 2005 at the Kyoto Protocol. Generally in the field of SF_6 gas insulated electric power facilities, about 30 % of the SF_6 gas is not reclaimed during factory routine test and about 20 % of that is not reclaimed during facilities maintenance and extension too. Unreclaimed SF_6 gases have been released into the air. So SF_6 gases usage reduction measures is required. We studied the electrical breakdown characteristics through AC withstand voltage test on GIB(Gas Insulated Bus) of 362 kV and 170 kV GIS, which were filled with eco-friendly and cheap dry air instead of SF_6 gas. The AC withstand voltage test was applied to the KEPCO(Korea Electric Power Corporation)'s standard 362 kV and 170 kV GIB with dry air and magnitudes of breakdown voltage of dry air were compared with that of SF_6 gas. We also calculated the experimental formula of breakdown voltage of dry air. From the experimental results, the standard formula of AC withstand voltage test of dry air was derived. Using the standard formula, we can know that the dry air can be used as substitution material of SF_6 gas in 362 kV and 170 kV GIB. We also confirmed the on-site usage of dry air by factory routine test. Also, we considered its application way.

2 ELECTRIC FIELD ANALYSIS

2.1 170 kV GIB

When dry air and SF_6 gas in 170 kV GIB is used with insulation medium, Ansys's Maxwell 3D which are an electric field analysis program is used in order to compare with electric field in the internal structure. 170 kV one and three phase GIB used in KEPCO are analysis objects. Assumes the case where the dry air filled by 1, 3 and 5 atmospheric pressures, electric field distributions of spacer which are a part which is most weak in breakdown is analyzed. Figure 1, 2 and table 1 are shown.

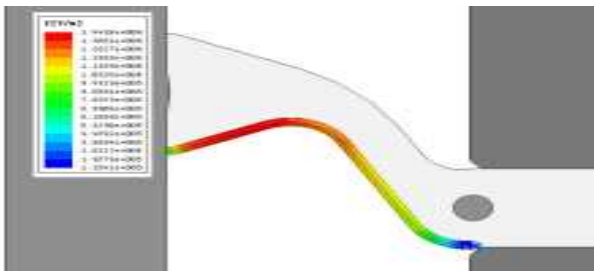

Figure 1: Electric field distribution of 170 kV 1 phase type Spacer

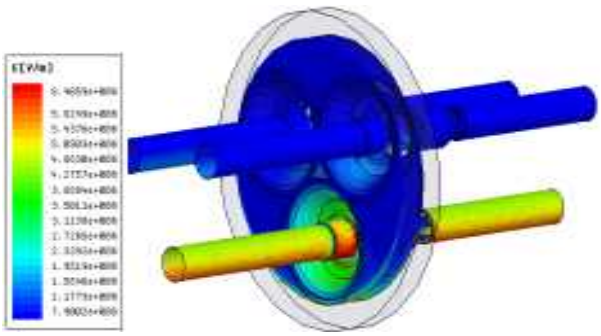

Figure 2: Electric field distribution of 170 kV 3 phase type Spacer

Table 1: Electric field strength with SF_6 gas and dry air

Condition / P.resurre [atm]	Maximum Electric field strength [kV/mm]			Breakdown Voltage [kV]			
	Dry Air		SF_6 gas	Dry Air		SF_6 gas	
	1Phase	3Phase	standard	1Phase	3Phase	Standard	3Phase
1	1.45	1.71	3.94	98.6	90.6	267.9	208.8
3	3.52	4.44	8.27	239.4	235.3	562.3	438.3
5	5.04	6.41	11.18	342.7	339.7	760.2	592.5

When dry air for insulation is used, breakdown voltage is calculated considered the maximum electric field strength. According to pressure's increase, breakdown voltage on spacer of one and three phase GIB tend to increase in figure 3. This is similar with SF_6 gas. The breakdown voltage of dry air has the uniform pattern compared with that of SF_6 gas. Therefore from electric field analysis result, it is known that dry air can substitute SF_6 gas in breakdown test of 170 kV GIB.

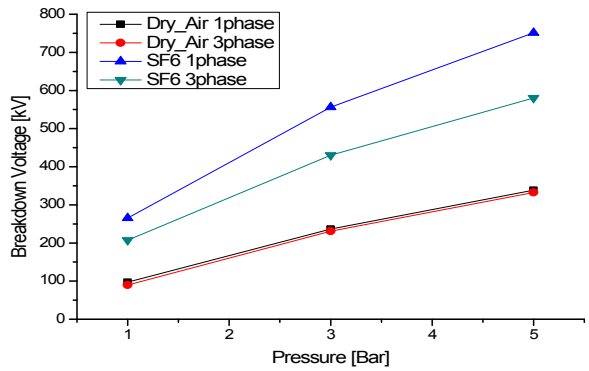

Figure 3: Breakdown voltage of SF_6 gas and dry air

2.2 362 kV GIB

Electric field distribution of 362 kV GIB is analyzed on post Insulator where is a part which is most weak in breakdown equally with analysis method of 170 kV GIB. Figure 4 and 5 and table 2 are shown.

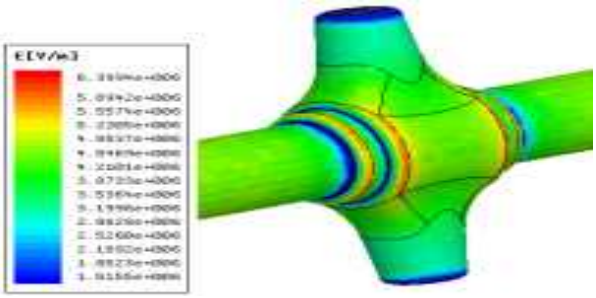

Figure 4: Electric field distribution of 362 kV 1 phase type Post Insulator

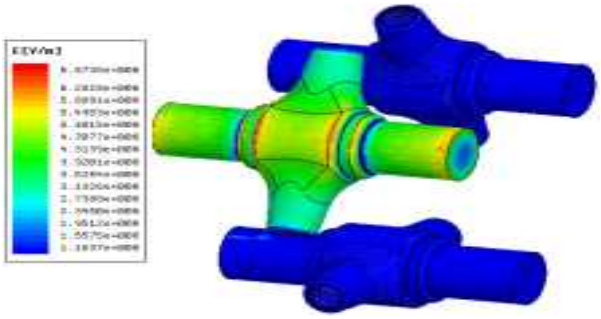

Figure 5: Electric field distribution of 362 kV 3 phase type Post Insulator

Table 2: Electric field strength with SF_6 gas and dry air

Condition / Pressure [atm]	Maximum Electric field strength [kV/mm]			Breakdown Voltage [kV]			
	Dry Air		SF_6 gas	Dry Air		SF_6 gas	
	1Phase	3Phase	Standard	1Phase	3Phase	1Phase	3Phase
1	2.41	2.07	3.94	151.2	113.9	248.7	217.1
3	5.42	5.41	8.27	341.5	297.6	521.0	454.9
5	6.40	6.87	11.18	403.2	377.9	704.3	614.9

According to pressure' increase in figure 6, breakdown voltage on post insulator of one and three phase GIB tend to increase similarly with 170 kV GIB. This is similar with SF_6 gas. The breakdown voltage of dry air has the uniform pattern compared with that of SF_6 gas. Therefore from electric field analysis result, it is known that dry air can substitute SF_6 gas in breakdown test of 362 kV GIB.

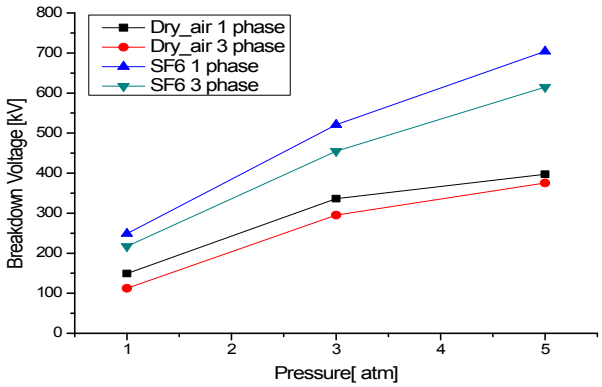

Figure 6: Breakdown voltage of SF_6 gas and dry air

3 EXPERIMENT RESULTS AND ANALYSIS

3.1 Experiment Equipment

Breakdown experiment are conducted for 170 kV and 362 kV GIB filled with dry air and SF_6 gas. The

configuration of experiment equipment is shown in figure 7 and output voltage of withstand voltage equipment is the maximum 800 kV and the component of dry air is shown in table 3.

Figure 7: AC withstand voltage test equipment configuration

Table 3: Components of dry air used in the experiments

Classification	Component	Composition
1	O_2	below 19.5 %
2	N_2	80 %
3	Dew Point	below -65 °C
4	Moisture content	below 10 ppm

3.2 Breakdown Experiment and Characteristics of 170 kV GIB

After assembling 170 kV GIB for AC withstand voltage test, a vacuum work is executed and maintained below 0.03 Torr. Dry air and SF_6 gas are filled from 1 atmospheric pressure to 5 atmospheric pressures and the moisture is maintained below 10 ppm. Breakdown voltage was measured, increasing voltage of AC withstand voltage epuipment every 1 kV. The dry air is filled with 1, 3 and 5 atmospheric pressures and SF_6 gas is filled with 1 atmospheric pressure of purity 95 % or more. Breakdown experiment is conducted 30 times or more in every condition. Beakdown experimental results for dry air is shown in table 4.

Table 4: AC breakdown voltage experimental results of dry air

Condition / Pressure [atm]	Breakdown Voltage by Experiment [kV]		Breakdown Voltage by Electric Field Analysis [kV]	
	1Phase	3Phase	1Phase	3Phase
1	97.4	89.9	98.6	90.6
3	236.8	230.9	239.4	235.3
5	338.7	332.8	342.7	339.7

Experimental data applied reliability segment 95% and experimental formula is derived from allometry methods using minimum breakdown voltage. In 170 kV one and three phase GIB, AC withstand voltage' experimental formula is shown in (1), (2).

$$V_{bd} = 98.156P^{0.7798} \quad \text{170 kV 1 phase GIB} \quad (1)$$

$$V_{bd} = 90.801P^{0.8204} \quad \text{170 kV 3 phase GIB} \quad (2)$$

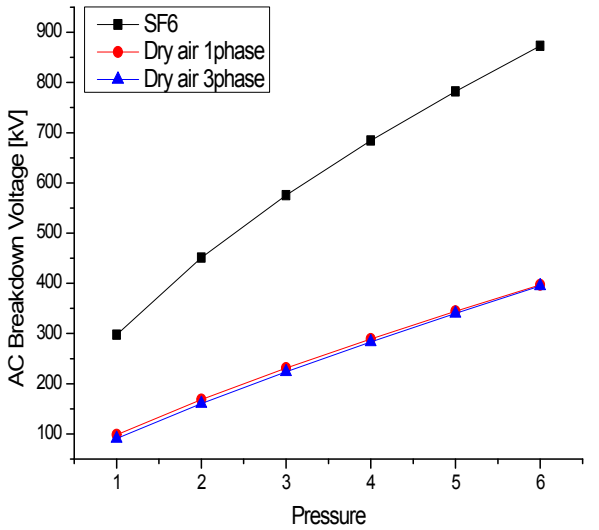

Figure 8: Breakdown voltage of dry air and SF_6 gas

Breakdown voltage calculated by AC withstand voltage' experimental formula for dry air and by electric field analysis for SF_6 gas are compared and the equivalence is confirmed according to pressure from figure 8. In table 4, the breakdown voltage by experiment is compared with that by electric field analysis and the effectiveness of experimental data was verified. From experimental result, we can know that the dry air can be used as substitution material of SF_6 gas at AC withstand voltage test of 170 kV GIB. It is reasonable to apply 170 kV three phase GIB's experimental formula to AC withstand voltage test. Because breakdown voltage of 170 kV three phase GIB is low compared with that of 170 kV one phase GIB. Probabilistic deviation σ, error coefficient K_1 and pollution coefficient K_2 is applied to experimental formula of 170 kV three phase GIB. So AC withstand voltage's standard formula is derived in (3).

$$V_s = 90.801P^{0.8204}\sigma K_1 K_2 \quad (3)$$

3.3 Breakdown Experiment and Characteristics of 362 kV GIB

Experiment for 362 kV GIB is conducted identically with 170 kV GIB. AC withstand voltage experimental results of dry air is shown in table 5.

Table 5: AC breakdown voltage experimental results of dry air

Condition / Pressure [atm]	Breakdown Voltage by Experiment [kV]		Breakdown Voltage by Electric Field Analysis [kV]	
	1Phase	3Phase	1Phase	3Phase
1	149.05	112.28	151.2	113.9
3	336.26	295.31	341.5	297.6
5	397.16	375.49	403.2	377.9

The method to obtain breakdown experimental formula is same with that of 170 kV GIB. AC withstand voltage' experimental formula in 362 kV one and three phase GIB is shown in (4), (5)

$$V_{bd} = 153.481P^{0.6299} \quad \text{362 kV 1 phase GIB} \quad (4)$$

$$V_{bd} = 115.579P^{0.7708} \quad \text{362 kV 3 phase GIB} \quad (5)$$

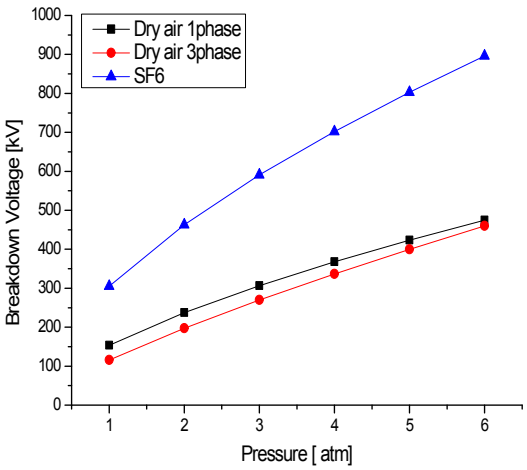

Figure 9: Breakdown voltage of dry air and SF_6 gas

The experiment result of 362 kV GIB is shown in table 5 and figure 9. From experimental result, we can know that the dry air can be used as substitution material of SF_6 gas at AC withstand voltage test of 362 kV GIB with 170 kV GIB identically. Probabilistic deviation σ, error coefficient K_1 and pollution coefficient K_2 is applied at experimental formula of 362 kV three phase GIB. So AC withstand voltage's standard formula is derived in (6).

$$V_s = 115.5791P^{0.7708}\sigma K_1 K_2 \quad (6)$$

4 CONCLUSION

In this paper we studied the electrical breakdown characteristics through AC withstand voltage test on 362 kV and 170 kV GIB of KEPCO, which were filled with dry air instead of SF_6 gas. Therefore we calculated the experimental formula of breakdown voltage of dry air. From the experimental results, the standard formula of AC withstand voltage test of dry air was derived. Using the standard formula, we can know that the dry air can be used as substitution material of SF_6 gas in 362 kV and 170 kV GIB. We also confirmed the on-site usage of dry air by factory routine test. Therefore we suggest the application possibility of dry air by factory routine test and It is expected the amount of SF_6 gas and the expense will be reduced.

5 REFERENCES

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