Study Committee A3

Transmission and Distribution Equipment

Paper 10317_2022

Experimental and Numerical Analysis of the Interruption Capability of SF_6-Free 245kV 63kA GCB

Jungho PARK*, Manjun HA, Kyongbo SEO, Hongkyu KIM, Joohyun LEE
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Introduction

- SF_6 gas is one of the most potent greenhouse gas with a global warming potential (GWP) about 23,000 times higher than that of CO_2.
- For this reason, a lot of research and development has been dedicated to finding an alternative gas to SF_6Indicate aim of study
- it is necessary to improve and change according to the flow characteristics of alternative gas
- the performance of GCB using the mixture of C4F7N and CO2 is evaluated experimentally and numerically, focusing on the SLF interruption capability of gas circuit breakers
- performance analysis through Computational Fluid Dynamics (CFD) had been done in parallel to evaluate the interruption capability of tested model
- the interruption capability of the 245kV 63 kA self-blast SF6-free gas circuit breaker was evaluated and an improved design was derived

Synthetic test model

- The interruption capability test had been done at the synthetic testing facility
- The commercial SF6 245kV 63kA GCB is used as a base model for the interruption test
- the interruption test was conducted with 1st peak value of Rate of Rise of Recovery Voltage (RRRV) as 12.5 kV/us

Table 1. Test condition

Rated Voltage	245kV
Rated short-circuit current	63kA
Rated frequency	50Hz
Types of interruption	Self-blast
Medium gas	CO_2(95%) + C_4F_7N
Test duty	SLF 90
Rate of Rise of Recovery Voltage (RRRV) of 1st peak	12.5kV/us

Influence factors for interruption capability – Pressure rise

- The initial design was carried out using two influencing factors that are easy to handle with the help of CFD analysis.
- The first factor is pressure rise in the heating chamber and the second is gas temperature out from the heating chamber

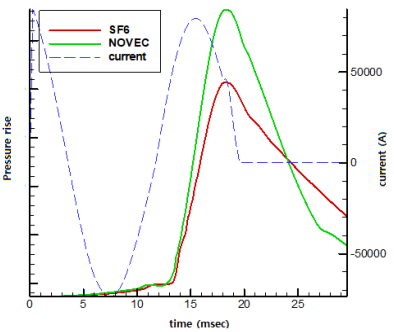

Fig 1. Pressure rise of 2 different gases

- It is known experimentally or theoretically that the pressure of CO2-based eco-friendly gas rises higher than that of SF6
- After the current peak time, the speed of outflow from heating chamber is also faster compared to SF6, resulting in quick pressure drop.

Influence factors for interruption capability – Gas temperature

- The temperature of the arc and outflow gas at the current zero is also very important in determining the interruption performance of the gas circuit breaker
- The temperature between the arcing contacts is related to the arc conductance of the gas circuit breaker and G(200ns), which is a widely-used index to evaluate the SLF interrupting performance of the gas circuit breaker
- Design modification has been done to minimize the arc temperature and outflow gas temperature from the heat chamber.

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CFD analysis – Numerical methods

- in-house code based axisymmetric 2D program was developed and validated for the study. Numerical method used in the program is listed in table 2

Table 2. Numerical schemes used in the paper

	scheme
Inviscid flux	AUSMPW+ (FVS)
Time integration	LU-SGS (implicit) Dual-time-stepping
Grid system	Structured grid Overset method
Radiation	DOM 11 bands with Planck averaging

CFD analysis – Validation

- The pressure in the heat chamber and arc voltage between the electrode had been validated as in Figure 2.

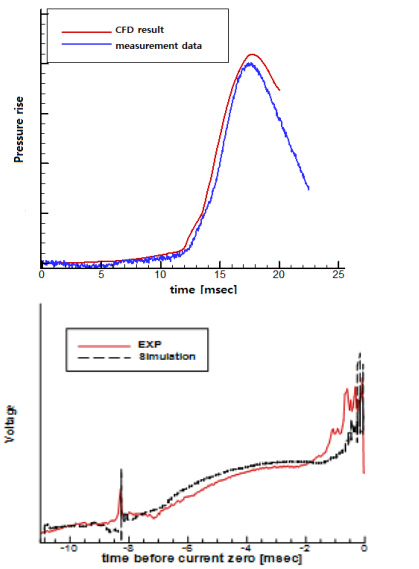

Fig. 2 Validation result of SF_6-Free Gas Circuit Breaker (C_4F_7N and CO_2 mixture)

CFD analysis – Design Modification

- Design modification has been done to increase and maintain the pressure and decrease the outflow and arc temperature at the current zero
- Significantly increase the pressure with mainly changing the shape of the nozzle
- The thermal chamber guide and the shape of thermal chamber was modified to increase the mixing effect of the heat gas

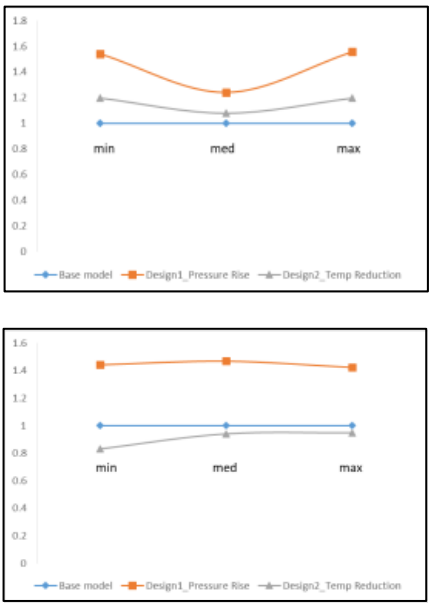

Fig 3. Pressure rise and Temperature at the channel of new design (C_4F_7N and CO_2 mixture)

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Test result and Discussion

- The baseline model is a 245kV 63kA 60Hz circuit breaker with SF6 gas that is commercially developed.

Table 3. Interruption test for commercial GCB

Gas	test RRRV	Filling Pressure	Success/Fail
SF6	14.6kV/us	6.5bar	O
CO2(95%)+ C_4F_7N	5.0kV/us	6.5bar	X
CO2(95%)+ C_4F_7N	5.0kV/us	8.0bar	O
CO2(95%)+ C_4F_7N	5.5kV/us	8.0bar	X

RRRV at 1st peak (kV/us)	Arcing time	Success/Fail	Test order
6.5	12.5 ms	O	1st
8		O	6th
9		O	9th
10		X	10th

Design for temperature reduction

RRRV at 1st peak (kV/us)	Arcing time(ms)	Success/Fail	Test order
9	12.5	O	1st
10.5	13.5	O	6th
12.7	13.5	O	9th

Table 4. Synthetic test result of interruption capability
Design for pressure rise

- In the case of the pressure rise design, the initial RRRV was successful up to 12.7kV/us
- There are cases where the post-arc current is up to 20~30 A, and there are cases where the post-arc current maintains over 10μs

Test result and Discussion

- In order to succeed in the HPL test, it is necessary to additionally find a design that can reduce the magnitude of the post-arc current within 5~10us
- The temperature reduction design showed a performance of RRRV 9kV/us. However, post arc current is small when successful test. Also, it disappears completely within 3μs.

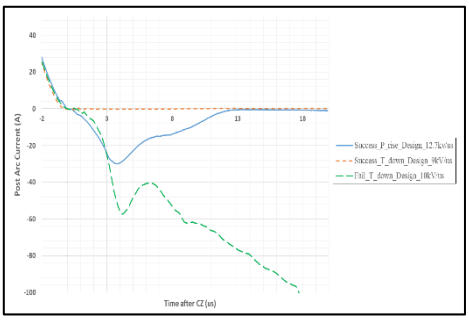

Fig 4. Measurement data of Post arc current for several cases

Conclusion

- This study includes the results of basic research conducted prior to the development of the 245kV 63kA self-blast type GCB using SF6 free, eco-friendly gas
- Modification of initial design such as the nozzle shape and thermal heating chamber had been done to increase the pressure and lower the temperature, and the interruption performance was evaluated using synthetic test facility. As a result, the interruption performance was improved compared to that of baseline model
- However, we found a problem that does not occur in the existing SF6 circuit breaker, such as the relatively large post-arc current, and an appropriate optimal design would be needed to reduce it. It is expected that this result can be useful for development of SF6-free 245kV 63kA GCB.

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