Numerical Investigation of Thermal Interruption Capability for Gas Circuit Breaker Adopting CO_2/O_2 Mixture

Hyun-Mo Ahn, Hyun-Jae Jang, HoJong-Ho Kang, Ki-Dong Song, and Yeon-Ho Oh*
Electrical Apparatus Research Division, Korea Electrotechnology Research Institute, South Korea

Sung-Chin Hahn
Korea Electrical Manufacturers Association, South Korea

Abstract

This paper presents a numerical investigation of the thermal interruption capability for the gas circuit breaker (GCB) adopting CO_2/O_2 mixture. The ohmic loss of the insulation gas is calculated from current continuity equation, and is utilized as a heat source for thermal fluid analysis. In order to accurately estimate the thermal interruption capability of a GCB adopting CO_2/O_2 mixture, we proposed an electric arc plasma model combining electric model and thermal fluid dynamics model. The validity of the proposed electric arc plasma model is verified by comparing it with experimental data. Subsequently, interruption indices are predicted using the calculated parameters to estimate the thermal interruption capability.

1 Introduction

In recent years, there has been growing concern about global warming, leading to increased interest in SF_6 free GCBs. Therefore, research on SF_6 free GCBs is essential for replacing the existing SF_6 GCBs currently in use.

The interruption capability of GCBs can be classified into two types: thermal interruption and dielectric interruption capabilities. The thermal interruption capability is estimated by using interruption indices such as G_{200}, which represents the arc conductance just before the arc is extinguished at 200ns from the current zero crossing, and post arc current (PAC), which represents the arc current within a few microseconds after the current zero crossing. On the other hand, the dielectric interruption capability is estimated by using a breakdown index based on the dielectric strength of the high temperature insulation gas in the region of maximum transient recovery voltage after arc extinction. In particular, in order to evaluate the thermal interruption capability of a GCB, it is essential to solve the complex physical problem arising from the arc plasma during the interruption process.

This paper deals with the numerical investigation of the thermal interruption capability for a 72.5kV GCB adopting CO_2/O_2 mixture. To estimate the thermal interruption capability of a GCB adopting CO_2/O_2 mixture, we proposed an electric arc plasma model that integrates an electric model and a thermal fluid dynamics model. The proposed electric arc plasma model calculates various parameters, including pressure, temperature, arc voltage, and other relevant parameters during the interruption process. Subsequently, in order to predict the thermal interruption capability, the interruption indices such as G_{200} and PAC are predicted by utilizing the calculated parameters.

2 The Electric Arc Plasma Model

In order to calculate the arc plasma in the GCB during the interruption process, it is essential to determine the heat source of the arc energy. the electric field problem required for calculating the heat source can be solved from the current continuity equation using electrical potential and electrical conductivity [1].

$$\nabla \cdot (-\sigma \nabla \phi) = 0 \quad (1)$$

The fluid flow, pressure, and temperature distribution in the GCB are calculated using three governing equations such as continuity, momentum, and energy equations [2].

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = S_m \quad (2)$$

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v} \vec{v}) = -\nabla P + \nabla \cdot (\overleftrightarrow{\tau}) \quad (3)$$

$$\rho \frac{\partial h}{\partial t} + \vec{v} \cdot \nabla (\rho h) = \nabla \cdot (\rho \vec{v}) + \nabla \cdot (k \cdot \nabla T) + S_e \quad (4)$$

In this paper, we deal with the electric arc plasma model of a 72.5kV GCB adopting CO_2/O_2 mixture. The calculated pressure rise and arc voltage obtained from the proposed electric arc plasma model are compared with experimental values as shown in Figure 1 and Figure 2, respectively. In order to estimate the thermal interruption capability, G_{200} and PAC are predicted using arc characteristic parameters.

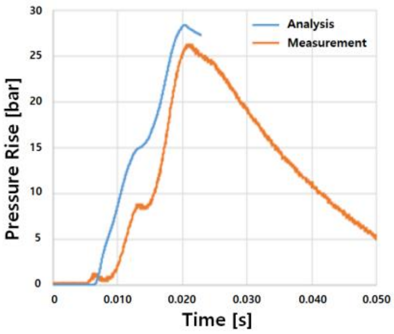

Figure 1: The pressure rise

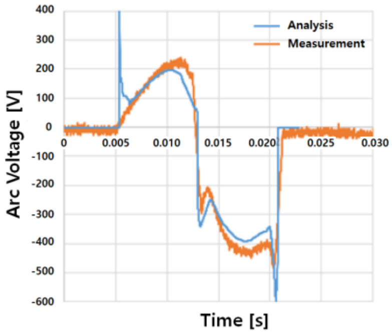

Figure 2: The arc voltage

3 Conclusion

This paper deals with the numerical investigation of thermal interruption capability for the 72.5kV GCB adopting CO_2/O_2 mixture. We proposed an electric arc plasma model that combines an electric model and a thermal fluid dynamics model. To increase the accuracy for estimation of the thermal interruption capability, we calculated the ohmic heating considering the electric conductivity that varies with pressure and temperature. In order to verify the validity of an electric arc plasma model, the calculated arc voltage was compared with the experimental values. Furthermore, we estimate the thermal interruption capability of a GCB adopting CO_2/O_2 mixture by utilizing interruption indices that are predicted using the calculated parameters. The numerical investigation of the thermal interruption capability will be useful for the interrupter design of the GCBs adopting CO_2/O_2 mixture.

References

[1] D. Godin, et. al, Modelling and simulation of nozzle ablation in high-voltage circuit-breakers, *J. Phys. D: Appl. Phys.* **33** (2000) 2583-2590.

[2] H. Nordborg, et. al, Self-consistent radiation based modelling of electric arcs: I. Efficient radiation approximations, *J. Phys. D: Appl. Phys.* **41** (2008) 135205.