Analysis of axial magnetic field of coil type vacuum interrupter electrodes by comparing effective area at mid-gap plane

Byoung-Chul Kim, Jae-Hun Yoon, Jun Hoe, Seong-Wha Kang, Kee Joe Lim
Chungbuk University, Chungcheong College

1. INTRODUCTION

Vacuum circuit breaker (VCB) is now emerging as an alternative of gas circuit breaker (GCB) which uses SF6 gas as an insulator whose dielectric strength is outstanding. But we have to reduce SF6 gas because SF6 gas is one of greenhouse gas and efforts to reduce greenhouse gas are now trend of the world. Therefore, we can say VCB is the optimal alternative of GCB because vacuum is environmentally friendly. The vacuum interrupter is the core part of VCB to interrupt arcing current. There are mainly two methods to extinguish arc. They are radial magnetic field (RMF) method and axial magnetic field (AMF) method. We deals with AMF method in this paper.

Compared with RMF AMF arc quenching method has different principle to extinguish arc. Figure 1 shows features of the interruption process and shape of arc in cases of RMF and AMF respectively.

In case of AMF arc quenching method, effective area of mid-gap plane is important because wider effective area means that the electrode can be prevented from severe damage by means of pinch effect in AMF which is parallel to current flowing through electrodes. This results in multiple slightly damaged spots. Therefore the more mid-gap plane has effective area, the better surface can be protected from being melted.

2. NUMERICAL APPROACH

2.1 Magnetic vector potential

\[ \nabla \times H = J_0, \quad \nabla \times (\nabla \times A) = J_0 \]

\[ \nabla \times E_x = -\frac{\partial A}{\partial t} + \nabla \Phi \]  

where \( J_0 \) is a case of conservative field, the solution can be expressed as following equation (4) as function of electric scalar potential.

\[ E_x = -\frac{\partial A}{\partial t} - \nabla \Phi \]

\[ J_x = -\sigma \frac{\partial A}{\partial t} + \nabla \Phi \]

2.2. Analyzed model

The external input current has to be continuous in calculation region.

\[ \nabla \times J_0 = 0 \quad \text{or} \quad J_0 = \nabla \times T \]

\[ \nabla \times E = 0 \quad \text{and} \quad J_x = \Phi \]  

\[ \nabla \times (\frac{1}{\sigma} \nabla \times T) = 0 \]

\[ v : \text{velocity}, \quad \sigma : \text{conductivity}, \quad \Phi : \text{electric scalar potential} \]

\[ J_0 : \text{external input current density,} \quad J_x : \text{eddy current density,} \quad T : \text{current vector potential} \]

2.3. Method of simulation

The numerical simulations were carried out with the 3-dimensional Finite Element Method commercial software Maxwell 3D. We have solved magneto-dynamic problems to take into account eddy currents effect(dy effect). We input sin wave external input current as a matter of convenience and its frequency was 60Hz.

We have already knowing the experimental equation by schulmann which correlates default current and minimum critical magnetic flux density to diffuse arc. We use 50kA as default current

\[ B_{critical} = 3.2(I - 9)[mT] \]
We could find critical magnetic field $B_{critical}$ by inserting the current of 50kA into the equation (9). The value $B_{critical}$ was 0.131 [mT].

(Figure 3) An example of calculation process

2.3. Result and discussion

(Figure 4) Distribution of AMF at mid-gap plane (a) at current peak, (b) at current zero

(Figure 6) An example of influence of the length of slot (4 segment coil type electrode)

3. CONCLUSION

In this paper, 3 kinds of axial magnetic field type vacuum electrode were analyzed and compared by means of 3D finite element method simulations. Especially, we used 'schulmann's experimental equation' and 'effective area' as comparison criteria.

As a result, the shape of effective area on contact electrode was influenced by the number of coil segments both at current peak and current zero and the magnitude of AMF has reverse proportion relation to the number of coil segments. This is related to the length of current path. The longer the path is, the more magnetic flux density generated by the current, which flows through the coil path, can be concentrated to a local spot on contact electrode. In the foreseeable future, we plan to calculate and analyze phase shift between source current and magnetic field caused by the current.

ACKNOWLEDGE

This research was supported by University Electric Power Research Center Enterprise of Korea Ministry of Commerce, Industry and Energy

[REFERENCES]

[3] [한국어 논문] "환자계형 전동 인터럽터에서 전자류의 영향에 관한 연구", 전기전자학회, 2002년 9월호, "한국 전도류화학적을 이용한 환자계형 전동 인터럽터의 특성고찰"