# 아크회전과 열팽창 방식을 적용한 소호부에 대한 아크유동 해석

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# The development of computational fluid dynamics tools for thermal expansion type interrupter with the arc rotary

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Abstract - This paper is concerned with the development of PC based computer simulation and design tools for auto-expansion SF6 circuit breaker with the arc rotary. The simulation model takes into account radiation transport, turbulence enhanced momentum, energy transport. The conversation gas dynamic equation together with Maxwells equations are solved. For the arc simulation the straightforward procedure has been used. The temperature, gas density and velocity space distributions within the circuit breaker are simulated in details. The presented results show that the computer simulation of gas flow in SF6 interrupter is a subject of much interest for design and *optimization of contacts*. The presented results show that the shape and sizes of contacts are chosen by this tool from judiciously compromise between electrical breakdown strength and interruption ability that are functions of gas flow parameters.

## 1. Introduction

In last years a new generation of circuit breakers known as the self-expansion circuit breakers has emerged as the main competitor to the technically more mature puffer circuit breakers. The most important advantage of auto-expansion circuit breaker is a utilization of the energy dissipated by the arcing to create the required conditions for arc quenching during the current zero period. Thus the energy required for the operating mechanism of an auto-expansion circuit breaker is much smaller than that of a puffer circuit breakers [1,2].

The using of the arc rotating pursues two goals. Firstly the arc rotation creates centrifugal force which during high current period inflates storage area by gas in addition. Secondly the arc rotation prevents the contact erosion because more uniform contact heating.

Since the condition s required for arc quenching and dielectric recovery in an auto-expansion circuit breaker are created by the arc itself, the development of such a breaker has proven to be much difficult. The flow conditions at current zero are governing by whole arcing period, and by a number of inter-dependent design parameters which are the dimensions of interrupter, the hot storage volume, the speed of contact motion, and an initial gas pressure.

This report is concerned with the development of PC based computer *simulation for* thermal expansion type interrupter with the arc rotary. An initial results of simulation are presented.

## 2. Governing equation, initial and boundary condition

The behavior of an arc, its surrounding gas flow are described by conservation law equations which can be written in the following general form:

$$\frac{\partial F}{\partial t} + \mathrm{div}(\mathrm{VF}) = -\mathrm{f} + \mathrm{g} \qquad (1)$$

Equation of state assuming a perfect gas

$$p = \rho RT \qquad (2)$$

Where p is a gas pressure, T is a gas temperature, R is a universal gas constant, g is a second order term. For energy equation it mean thermal conductivity term.

$$F = \begin{pmatrix} \rho \\ \rho u \\ \rho v \\ \rho e \end{pmatrix};$$

$$f = \begin{pmatrix} 0 \\ \frac{\partial p}{\partial r} \\ \frac{\partial p}{\partial z} \\ \frac{\partial pu}{\partial r} + \frac{\partial pv}{\partial z} - \sigma E^2 - q \end{pmatrix}$$

Equation (1) implies the conservation law of mass , momentum V and energy e.

Axis symmetry is assumed when solving (1). The equations are based on local thermal equilibrium (LTE). Thus the transport properties and electric conductivity are determined by enthalpy and pressure as given for SF6 in [3]

Input power is computed from the current continuity equation and Ohms law.

$$\nabla j = 0 \qquad (3)$$

$$j = \sigma E \qquad (4)$$

The calculation domain is broken in a rectangular mesh. As boundary condition for gas dynamic equations we use contact storage area surfaces As initial data we introduce uniform initial values of gas density, pressure and gas temperature.

In the energy equation q presents the net radiation loss per unit volume and time. Here we use data [4] which are not in agreement with experiment [5]. Authors of [5] receive bigger value q than calculated one about a few times. Unfortunately there are no any another calculated data and basically [2] a correction coefficient is introduced. We did not introduce correction coefficient, but for q we use biggest value corresponding smallest arc radii.

Well-known FLIC(fluid in cell) method [6] is used for computer simulation

## 3. Computational result and discussion

A figure 1 show us electrical field distribution on contact surface for a second zero. The field distribution is non-uniform. We can see sharp rise of a field near an outer border of fixed contact.

Figure 2 show us a few temperature distributions. We show pictures for 0.03, 0.07 and 0.01ms after a contact breaking. The first picture is corresponded to initial stage and show a formation a hot gas area with temperature about 18 000K between contacts. At this temperature gas conducts electrical current well. The simulation results indicates the most of input power at this stage is lost by arc radiation. The contribution of thermal convection in axial direction is small due to low pressure at the arc area. A second time corresponds to the first current zero. We can see a decrease temperature to a value about 10000K due to the lack of input power and the radiation. The main cooling process becomes a thermal conductivity in radial directions. The third picture correspond to developed arc. We can see area between contacts with high temperature. The temperature distribution inside arc is uniform due to high level of electron thermal conductivity. A size of border between arc and surrounding gas is determined by radial thermal conductivity. For all events pressure distributions are uniform in radial. So it means that lowest gas density area are located near contact axis at highest temperatures.

It is needed to point that the highest electrical field area and lowest gas density area are located separately. We know that electrical breakdown ability is determined by a few factors like a ratio electrical strength and gas density E/, size of stressed area, contact surface condition [7]. The most important is a E/. So we can optimize contact surface to decrease the E/, in respect to create the required conditions for arc quenching during the current zero period and the subsequent dielectric recovery period for fixed arc current.

We have to point the using of straightforward procedure for arc simulation. The complexity of arc phenomena that include a few cooling processes like radiation and turbulence energy transport which are determined through arcing leads to abandoning of two zone model.

It should be particular emphasized the importance data of net emission coefficient and turbulent thermal conductivity coefficient that are not known exactly. The simulation results depend critically on these data. We hope to obtain correct one from following experiments.

The work clearly demonstrated that the straightforward procedure of arc simulation with correct arc physics and with appropriate boundary condition could be used as a design tool to aid development of auto-expansion circuit breakers.

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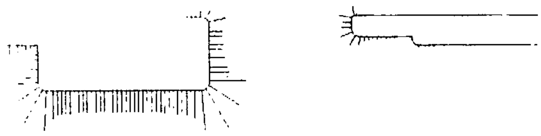

Figure #1 Typical electrical field distribution on contacts surface

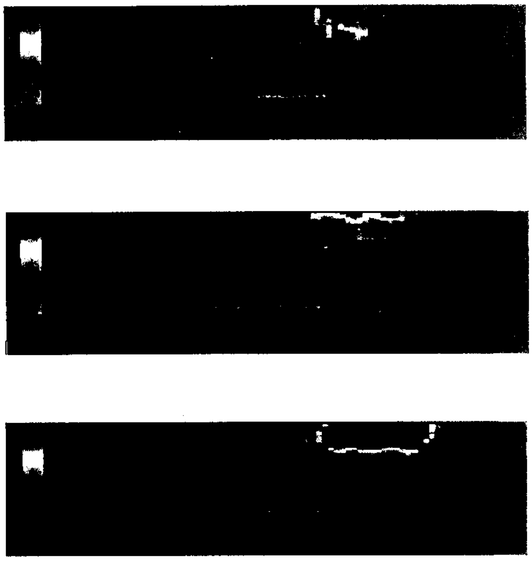

Figure #2 Gas temperature distribution for different times