# Calculations of Eddy Current, Fluid and Thermal Fields in an Air Insulated Bus Duct System

S.L. Ho[1], Y. Li[2], X. Lin[2], Edward W.C. Lo[1], S.Y. Yang[1], K.W.E. Cheng[1] and K.F. Wong[1]
[1]The Hong Kong Polytechnic University, Hong Kong
[2]Shenyang University of Technology, Shenyang, 110023, P.R.China
eeslho@polyu.edu.hk

**Abstract—A three-dimensional eddy current field model for calculating the eddy current losses in an air insulated bus duct system is proposed. The temperature rises are evaluated using the coupled fluid field and the thermal field model. Good agreement between the computed and test results confirms the proposed methodology is a viable approach to the study of practical system.**

## I. Introduction

Air insulated bus duct system (AIBDS) consisting of copper conductors and steel enclosure is used extensively in low voltage power distribution systems [1]. The copper losses in the conductors and eddy current losses in the enclosure may give rise to intolerable temperature rises if the AIBDS is not designed properly [1][2]. Because of large air space in AIBDS, the heat energy arising from copper loss is transferred, firstly from the conductor to the outer enclosure by convection and then from the enclosure to the ambient by convection and radiation. Due to the complexity of the heat path, the temperature rise in AIBDS cannot be evaluated readily using traditional heat conduction method only [2][3]. The coupled eddy current, fluid and thermal fields must be solved collectively when computing the temperature rise in AIBDS.

In this paper, a three-dimensional (3D) eddy current field model to calculate the losses is described and then the coupled fluid field and thermal field are solved. The convection of air inside the enclosure and the thermal conduction in the solid materials are all computed. A typical AIBDS is studied with both computed and test results reported.

## II. Formulations

To analyze the losses in the AIBDS as shown in Fig.1, the 3D eddy current field satisfying the following equations has to be evaluated first.

$$\nabla\times\nu\nabla\times\dot{\mathbf{A}}-\nabla\nu\nabla\cdot\dot{\mathbf{A}}+\sigma\nabla\dot{\phi}+j\omega\sigma\dot{\mathbf{A}}=\mathbf{J}_S \quad \text{in } V_1+V_2 \quad (1)$$

$$\nabla\cdot(-\sigma\nabla\dot{\phi}-j\omega\sigma\dot{\mathbf{A}})=0 \quad \text{in } V_1 \quad (2)$$

where, $V_1$ is the eddy current area, $V_2$ is the non eddy current area, $\mathbf{J}_s$ is the source current density.

At steady-state, the natural convection inside the AIBDS satisfies the following Navier-Stokes equations [1]:

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0 \quad (3)$$

$$\rho u\frac{\partial u}{\partial x}+\rho v\frac{\partial u}{\partial y}+\rho w\frac{\partial u}{\partial z}=\mu\nabla^2 u-\frac{\partial P}{\partial x}+Sx \quad (4)$$

$$\rho u\frac{\partial v}{\partial x}+\rho v\frac{\partial v}{\partial y}+\rho w\frac{\partial v}{\partial z}=\mu\nabla^2 v-\frac{\partial P}{\partial y}+Sy \quad (5)$$

$$\rho u\frac{\partial w}{\partial x}+\rho v\frac{\partial w}{\partial y}+\rho w\frac{\partial w}{\partial z}=\mu\nabla^2 w-\frac{\partial P}{\partial z}+Sz \quad (6)$$

$$\rho c u\frac{\partial T}{\partial x}+\rho c v\frac{\partial T}{\partial y}+\rho c w\frac{\partial T}{\partial z}=k\nabla^2 T+Q \quad (7)$$

Assuming the losses of the copper busbars and enclosures as the heat source in AIBDS, their corresponding temperature rises can be computed using indirect coupled method.

## III. Calculations of a 1600A AIBDS

A 1600A AIBDS structure is designed with its eddy current field, losses and temperatures computed using the proposed algorithm. Table I gives the losses and Fig.2 shows the temperatures of the busbar, air and enclosure in the scheme.

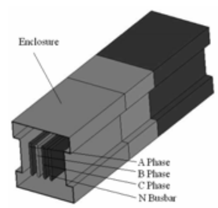


Fig.1 The structure of a AIBDS

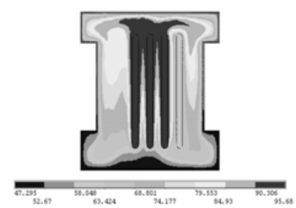

Fig. 2 The temperature of the AIBDS

TABLE I
Losses in the Busbars and Enclosure in a 1600A AIBDS (W/m)

| N-phase busbar | A-phase busbar | B-phase busbar | C-phase busbar | Enclosure |
|---|---|---|---|---|
| 0.46 | 94.2 | 98.4 | 93.7 | 4.6 |

TABLE II
Tested and Calculated Results of Temperature Rise (K)

| | A-phase busbar | B-phase busbar | C-phase busbar | Enclosure |
|---|---|---|---|---|
| Computed | 58.2 | 63.5 | 58.1 | 22.8 |
| Tested | 63.8 | 65.9 | 62.3 | 20.8 |
| Error (%) | -8.8 | -3.6 | -6.9 | 9.6 |

In order to check whether the AIBDS complies with the design, a real bus duct is built and Table II shows the test and computed temperature rises. As the maximum temperature rise limit of the hottest spot in the enclosure and busbar should be less than 30K and 70K, respectively, the temperature rises in the design scheme are deemed satisfactory. Moreover, one can conclude that the good agreement between the computed and measured temperature rise on the busbar as shown in Table II is a good validation of the proposed methodology.

## IV. References

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