Modeling of Streamers in Transformer Oil using OpenFOAM

Nils Lavesson[1], Jonathan Fors[2,1], and Ola Widlund[1]

[1] ABB Corporate Research, Forskargränd 7, SE-72178 Västerås, Sweden nils.lavesson@se.abb.com, ola.widlund@se.abb.com
[2] Linköping University, SE-58183 Linköping, Sweden jonathan@modulus.se

Summary. Streamers occur prior to breakdown in electrical insulation and understanding streamers is important in order to optimize insulation design. In earlier works a model that describes streamers in transformer oil has been developed and implemented in a finite element simulation tool. In this paper the consequences of changing simulation method to the finite volume method is investigated and the simulation is extended from 2D axial symmetry to 3D.

1 Introduction

When electricity is transmitted over large distances in a power grid high voltages are required to limit the ohmic losses. High voltage puts a number of demands on electrical equipment in particular the electric insulation. For power transformers the insulation systems usually consists of mineral oil and high density cellulose. The primary mode of failure is an electric arc though the oil, which normally destroys the transformer.

Before an electric arc is formed a pre-breakdown event called a streamer occurs. The streamer is an ionizing wave traveling rapidly through the oil. The wave starts when the oil gets highly stress causing excessive build up of charge, which in turn affects the electric field leading to a high electric field region nearby. The strong electric field causes additional ionization and the wave propagates.

2 The Streamer Model

Researchers at Massachusetts Institute of Technology (MIT) have together with ABB Corporate Research developed a model for describing streamers in transformer oil [2–5]. The model consists of ion and electron transport equations coupled with Poisson's equation. The ions and electrons are produced through a field dependent ionization term based on the Zener model for electron tunneling.

3 Numerical Methods

The streamer simulations at MIT have been done using Comsol Multiphysics, which is a computational tool based on the finite element method (FEM). Although Comsol is a powerful tool with a large number of applications, it has its limitations when computing convectively dominated flow, which is the main part of the streamer model. To be able to run the simulation various artificial diffusion techniques needs to be applied to stabilize the solutions.

A preferred method for convection dominated problems is the finite volume method (FVM). When implementing the MIT model in FVM OpenFOAM was chosen due to its flexibility and open structure. Moving to FVM also make the simulations more efficient, which allows larger problems to be treated.

4 Results

The MIT model was implemented in OpenFOAM at ABB and has been tested as part of the master thesis by Jonathan Fors [1]. The geometry simulated is a needle-sphere geometry, which is a standard geometry for testing the breakdown strength of insulating liquids.

The new solver is checked against a selection of MIT results [2]. These test cases are all 2D axisymmetric and include different model parameters and voltages. Most cases give quite similar results, but some differences are seen which are attributed to more stable numerics in the OpenFOAM solver.

The new solver has also been applied to a 3D version of the same needle-sphere geometry. The heavy computational load means that techniques for efficient meshing need to be used.

References

1. J. Fors. Modeling of streamers in transformer oil. Master's thesis, Linköping University, Linköping, Sweden, 2012. In preparation.
2. J.G. Hwang. *Elucidating the mechanisms behind prebreakdown phenomena in transformer oil systems*. PhD thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2010.
3. J.G. Hwang, M. Zahn, L.A.A. Pettersson, O. Hjortstam, and Rongsheng Liu. Modeling streamers in transformer oil: The transitional fast 3rd mode streamer. In *Properties and Applications of Dielectric Materials*, ICPADM, pages 573–578, 2009.

4. F. OSullivan. *A model for the initiation and propagation of electrical streamers in transformer oil and transformer oil based nanofluids*. PhD thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2007.
5. F. O'Sullivan, J.G. Hwang, M. Zahn, O. Hjortstam, L. Pettersson, Rongsheng Liu, and P. Biller. A model for the initiation and propagation of positive streamers in transformer oil. In *Electrical Insulation*, ISEI, pages 210–214, 2008.