Heat Transfer Coefficients Determination of Numerical Model by Using Particle Swarm Optimization

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***Abstract*— This paper presented a method for determination of heat transfer coefficients for FEM housing model of medium voltage switchgear cell. Suggested method is based on the PSO optimization algorithm. For that purpose, a real test model of partition wall has been created as well as an equivalent numerical FE model. Since the preciseness of thermal model is dependent on the preciseness of thermal coefficients, the goal of the optimization procedure is to assure even better matching between the measured and the FE model-calculated temperature values.**

Because of fact, that the temperature field is a consequence of eddy currents that appear in metal parts of switchgear devices, this paper deals with coupled problem. Non-linear calculation of magnetic field is also taken into consideration.

***Index Terms*—Thermal analysis, eddy currents, Particle swarm optimization, thermal factors.**

I. Introduction

Parameter identification is part of the so-called inverse problems and as such it is present in numerous different fields of electrical engineering [1]-[5].

During the consideration of thermal problems, where temperature crosses through processes of conduction and convection, there are two types of thermal coefficients that are necessary for a successful numerical calculation of temperature. These two are thermal conductivity and heat transfer coefficients used in a numerical analysis of the thermal field [6], and are usually given by tables. The values are also presented with a lower and an upper bound that presents an additional dilemma, which value to choose.

This paper describes a determination of heat transfer coefficients on the test object by using Particle swarm optimization algorithm (PSO) [7]. There are two models, which are required for this kind of analysis. The first is a test object of a simplified partition wall, onto which the temperature measurements are performed. The second is a numerical model, with which the temperature is calculated. The thermal field, which is discussed in this research, is a consequence of eddy currents that occur in metal parts of switchgear.

In one of the previous researches [8], for a similar example of switchgear cell, there is already calculated thermal conductivity with an optimization algorithm DE. But, heat transfer coefficients are not part of those researches, because coefficients as recommended values have been chosen from literature.

The main emphasis in this paper is the calculation of heat transfer coefficients of a partition wall (above, under and on the side). This type of procedure is more demanding than the calculation of thermal conductivity, and that is why a new set of measurements with a horizontal positioning of a test model, have been necessary.

II. Determination of Heat Transfer Coefficients by Using Optimization Algorithm

The simplified partition wall test object contains two holes. The conductors with a test current of 250 A are placed through the holes and the temperature measurements are made with fourteen thermocouples that are positioned as it is shown in Fig. 1a. The corresponding numerical model of a real device is shown in Fig. 1b. The complete model is built with two parametric preprocessors (eddy currents and a thermal one) and also with a numerical and graphic postprocessor.

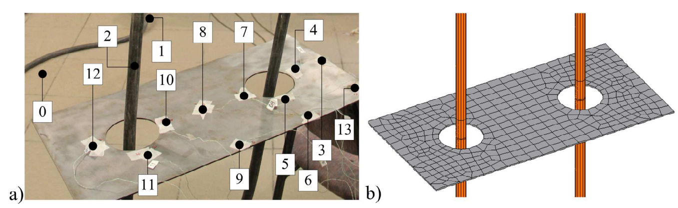

Fig. 1. a) Test object model of the partition wall with the positioned thermocouples, b) numerical FE model

Measured temperature values for all fourteen thermocouples, at the RMS current of 250 A through the conductor, are shown in Fig. 2.

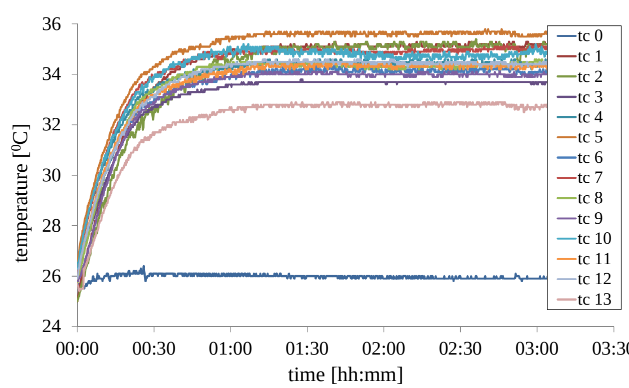

Fig. 2. Measured temperature values at RMS current 250 A

Determination process for heat transfer coefficients runs inside the Particle swarm optimization algorithm (PSO) and it is schematically shown in Fig. 3.

Perform temperature measurements on a real model (with thermocouples)
Create initial population of PSO algorithm (size *NP*)
While the stopping criterion is not reached **Do**
For *i*=1 to size of the population *NP* **Do**
Create preprocessor_1 (eddy current problem)
Compute the non-liner eddy current problem
Numerical postprocessor_1 (obtain Joule losses in each FE)
Create preprocessors_2 (thermal problem)
Compute the thermal field (temperature distribution)
Numerical post_processor_2 (temperature values at the same points as thermocouples)
Evaluate the objective function f_i (RMS between calculated andmeasured temperature values in *n* points)
End
If (f_i < required condition) **Then**
The numerical model is calibrated.
Optimal parameters of the optimization process are actual **heat transfer coefficient** of test model
Else
Update population - *new values* of optimization parameters
End
End

Fig. 3. Pseudo-code of the calibration process for optimization parameters

III. Results

Two types of calculation of heat transfer coefficients will be conducted. During the first calculation, thermal conductivities will be fixed defined values – taken from the tables. For the second calculation, thermal conductivities will also be optimization parameters. Comparison of those results will be presented in full paper. At the same time a comparison of obtained results with an analytical calculation will be also shown.

For the first example, where the subjects of optimization are only heat transfer coefficients, optimization algorithm deals with three parameters. Those are: h_u – heat transfer coefficient on the upper part of a partition wall, h_b – heat transfer coefficient on a bottom part of a partition wall, h_s – heat transfer coefficient on the vertical side of a partition wall.

In the second example, where thermal conductivities are additionally added to the optimization, four more parameters are obtained. Those are: k_a – thermal conductivity of air, k_w – thermal conductivity of partition wall, k_i – thermal conductivity of insulation, and k_c – thermal conductivity of conductor.

Convergence course of the optimization process for the first example with three parameters (heat transfer coefficients) is shown in Fig. 4. Due to a low number of optimization parameters, the optimization process quickly converges.

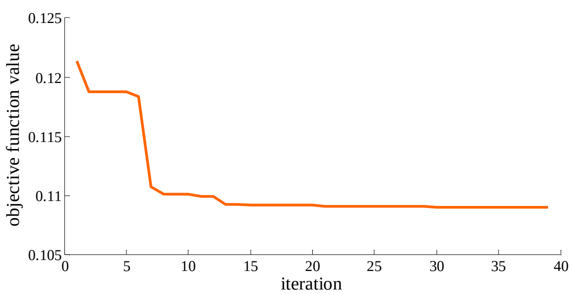

Fig. 4. Convergence of optimization algorithm

Fig. 5 presents the course of the best value of each parameter in each iteration, for that particular optimization process.

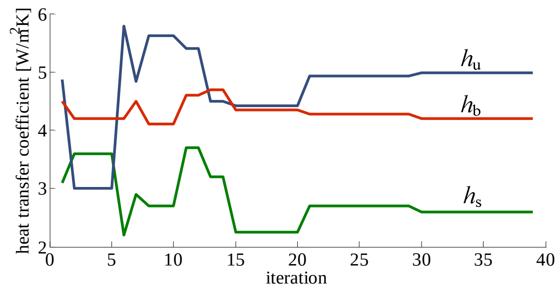

Fig. 5. The best individuals throughout the optimization process for each iteration and each parameter

IV. Conclusion

The aim of this research is to improve parameters of the numerical thermal model. Numerical model is calibrated when calculated and the measured results achieve a good agreement.

The complete results of the optimization process, as well as the description of the PSO optimization algorithm, will be presented in the full paper.

For the purpose of verification of the used PSO algorithm, an optimization with Differential evolution (DE) algorithm will be conducted in full paper.

A large number of measuring points can cause some problems in objective function calculations. The optimization algorithm can produce an illogical result, respectively an incorrect combination of the thermal parameters. A solution for this problem will also be presented in full paper along with a partitioning of an entire model into individual areas.

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