# Modeling of the heat transfer in the switchboard cabinet

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*Abstract*—**This paper deals with the modeling of a heat transfer in the switchboard cabinet by using the COMSOL Multiphysics software. The heat transfer field distribution can be seen from a typical example and discussion of its results. Furthermore, the results of simulations and performed measurements are compared for the selected cooling variant.**

*Index Terms*—**switchboard cabinet, heat transfer, simulation**

## I. Introduction

Currently, work on the paragliding flight simulator is in progress. The project fundamentally changes the possibilities of paragliding training, increases safety and reduces the risks of paraglider pilot's injuries. It can faithfully simulate conditions caused by pilot's mistakes. This simulator requires a special switchboard. One of the important issues was the cooling system of the switchboard cabinet design. For this purpose, the main heat sources were found in the switchboard and the cooling system was simulated. The aim of this paper is to replace time comsuming switchboard testing with an effective simulation of the temperature field.

## II. Switchboard cabinet construction

The switchboard is designed for operation under normal ambient conditions for the temperature range -20 °C and 70 °C [1]. To protect the components and the correct operation of the device, it is important to maintain the internal switchboard temperature in the range of 20 °C to 25 °C by correctly sizing the switchboard during design and adjusting the temperature using appropriate means. The main heat sources are converters, which task is to control the servo motors. There are also the smaller sources of heat and those are two direct voltage sources. They are used for supplying microcontrollers with electric energy. The heat, that arises due to microcontrollers, is in simulations neglected. The issue of the cooling system is shown in Fig. 1.

The switchboard cabinet consists of two main parts. In the bottom part, converters, control circuits for controlling servo motors, are situated. In the upper part are located voltage sources, circuit breakers, and other protective elements.The air flows through the grill, which is placed in the bottom part, to the ventilators in the upper part. The dimensions, of one switchboard cabinet, are 800 x 600 x 300 mm [1].
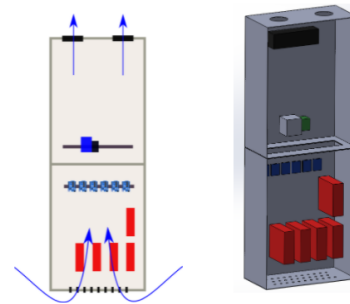


Fig. 1. Switchboard cabinet cooling choice (left) and model of switchboard cabinet (right)

## III. Heat transfer field simulation

The mathematical model of the temperature field is described by the Fourier-Kirchhoff's partial differential equation (1).

$$-div\lambda \cdot gradT + \rho \cdot c_p \cdot \frac{\delta T}{\delta t} = p \qquad (1)$$

where $\lambda$ is a thermal conductivity, $T$ is the temperature, $\rho$ is a specific weight of the material, $c_p$ is a heat capacity and $p$ represents external the heat sources.

The airflow in the switchboard is described by the Navier-Stokes's partial differential equation (2).

$$\rho \frac{\delta \vec{u}}{\delta t} - \eta \cdot \nabla^2 \vec{u} + \rho(\vec{u} \cdot \nabla)\vec{u} + \nabla p = \vec{F}, \qquad (2)$$

$$\nabla \cdot \vec{u} = 0,$$

where $\rho$ is density, $\eta$ is dynamic viscosity, $\vec{u}$ is field of the velocities, $p$ is pressure and $\vec{F}$ is force field intensity.

The temperature distribution in the switchboard is influenced by the air flow. The computer model was solved in the COMSOL Multiphysics software [2] and consists of two coupled physical fields. Heat transfer depends on the flow of the surrounding air.

The heat distribution in the switchboard cabinet without air flow is depicted in Fig. 2.
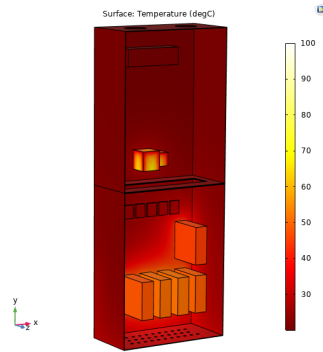
Fig. 2. Distribution of the temperature without air flow

In the next part, we considered the value of the heat transfer coefficient $\alpha = 20$ W·m$^{-2}$·K$^{-1}$, which represents natural cooling. The initial temperature was 20 °C. The temperature distribution in the switchboard cabinet is shown in the Fig. 3. The converters, as the temperature sources, worked only a partial power during the simulation.
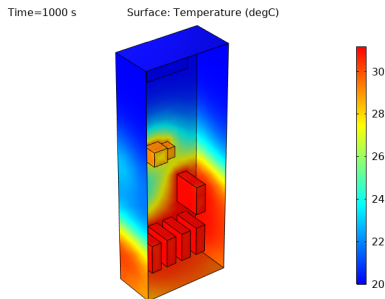


Fig. 3. Temperature distribution with natural cooling

Fig. 4 shows the temperatures obtained from the simulation. These temperatures are compared with the temperature values from the measurements. The initial temperature for the simulation was 29 °C as well as the temperature in our laboratory during the experiment.

The EasyLog Dual Channel Thermocouple Data Logger was used to measure the temperature. This device was put into the switchboard. During the measurement, the maximum load was applied to the servo motors. The peak current value that the converters received was approximately 2.5 A.
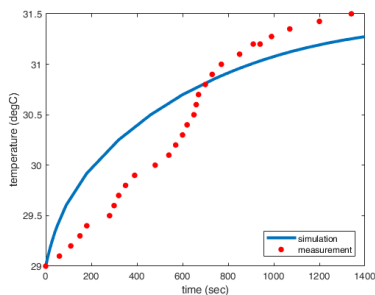


Fig. 4. Temperature in the switchboard cabinet with nature cooling.

During real operation of the simulator, the individual converters become more hot due to switching losses, current consumption and dynamic braking. All these aspects will be included in the model according to the measurements during the operation of the simulator.

There are a number of ways to dissipate heat from the switchboard. The internal temperature was calculated and it was found that the thermal limits of some devices were exceeded. Natural ventilation is not sufficient. During the simulation the value of the heat transfer coefficient $\alpha = 150$ W·m$^{-2}$·K$^{-1}$ is used. This value of coefficient $\alpha$ represents forced cooling. The initial temperature is 29 °C. All other variables were the same as in the previous simulation with the nature cooling. For the forced cooling, two ventilators are used, which are located on the upper part of the switchboard cabinet. The input power of those ventilators is 5W and they are supplied by 24 V DC.

The temperature of this simulation is shown in the Fig. 5 together with the measured values.During the measurements in our laboratory, the temperature was 29 °C, so the temperature inside the switchboard was lower than the initial value due to forced cooling.

The steady state value we obtained from the forced cooling simulation is approximately 21.9 °C. The same value was obtained during the measurement when two ventilators were used. This temperature is suitable for the operation of all devices in the switchboard cabinet.
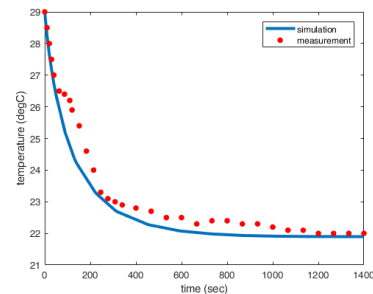


Fig. 5. Temperature in the switchboard cabinet with forced cooling.

IV. CONCLUSION

This paper presents a simulation of heat transfer in a switchboard. Illustrative examples show that we are able to simulate the heat transfer behavior inside a switchboard cabinet. Different types of simulators will be constructed, a special switchboard will be designed for each simulator and the simulation will save time with testing these switchboards.

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