3D MODEL TO ANALYSE THE THERMAL BEHAVIOR
OF A DIGITAL RECTIFIER

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Abstract. The continuing substitution of analog by digital modules in medium and large size telecommunication systems, have been contributing to highlight the importance of studying the thermal behavior in these equipments. It is well acknowledged that large amounts of energy is dissipated in small areas (electronic components), in such a class of system. One can observe convection transport driven by density gradients and/or by forced ventilation. The aim of this study is to investigate the thermal behavior of a digital rectifier located inside a telecom cabinet. A 3D numerical model, based on computational fluid dynamics, was constructed to represent the whole package. For simplicity only components that have the most representative size and power dissipation were considered. Results concerning different rectifier configurations (such as components arrangement and ventilation entrance/exhaust) are presented in order to identify deficient ventilation and high temperature regions.

keywords: Electronics packaging, Cooling electronics, Thermal analysis.

1. INTRODUCTION

One of the greatest challenges for the electronics industry during the past decades has been to seek out ways of reducing the operating temperature of electronics components. Problems related to the reduction of size and cost of systems that employ electronic components have also to be faced, considering the increment of power dissipated in smaller volumes, as a result of the enhanced capability of the electronic design and manufacture (Steinberg, 1991 and Azar, 1997).

Among all the factors that contribute to failures in electronic based systems, the occurrence of high temperatures is still the most common case. A basic heat transfer analysis has to ensure that the heat dissipated from each component is able to reach the surrounding ambient air.

In communications systems, the concerning about the temperature operation conditions are observed in a sense to allow such kind of assemblies to work for extended periods of time no matter the environmental conditions. As an example, some telecommunications cabinets, so called shelters, are designed to protect its internal electronic components and assemblies from ambient temperature ranging from $-33\,^{\circ}C$ to $55\,^{\circ}C$.

Depending on the external environment, the operational conditions are obtained according to natural or forced convection driven processes, employed in order to flush out the hot air generated inside the domain.

Lately, the employment of digital technology in substitution of the analog one, has increased the importance of monitoring the temperature levels in components and assemblies placed inside telecom cabinets.

The present work proceeds an investigation on the thermal behavior of a digital rectifier to be placed inside a telecom cabinet. A simplified model was constructed to simulate the thermal behavior of the unit, including its components. Simulations were performed employing a CFD numerical package (FLOTHERM), (Flomerics, 1998) by which was possible to identify potential problems early in the project. Several situations were tested in order to achieve the best unit configuration, considering the heat dissipated by its critical components and the air ventilated throughout the module.

2. PROBLEM CHARACTERIZATION

The unit under investigation is a modular rectifier, with size (424x111x112,2) mm, which operates in both 110/220V, designed to function inside a medium and/or large size telecommunication unit (shelter class). For this reason, the ambient temperature in which the rectifier is supposed to function corresponds to the temperature observed inside the shelter (Telebras, 1996). The main characteristic of this rectifier is to control and check the shelter operation parameters via a friendly interface based on digital technology, which also permits the diagnosis of several malfunctions that may occur. According to the system requirements, the rectifier assembly can reach up to four modules. Table 1 shows the total power dissipated by a single module (control module included), as function of the voltage.

Table 1. Total power dissipated by a single module.

Voltage [V]	Total power dissipated [W]
110	134,5
220	102,6

2. THERMAL MODELING AND NUMERICAL SOLUTION

A 3D computational model is constructed taking into account the material thermal properties, such as thermal conductivity and diffusivity (Touloukian *et al*., 1970). The geometry of all the components, the fan curves (in case of forced ventilation) and environmental constraints (initial and boundary conditions) are also considered. Of course, the success of the thermal design (numerical simulation) is extremely dependent on the reliability of all the parameters already mentioned, including the power dissipated by each component.

The approach to the solution of thermal problem is based on the differential form of transport equations and the numerical domain is solved using a CFD code (FLOTHERM version 2), which is based on finite volume method (Patankar, 1980).

4. RESULTS AND DISCUSSION

The FLOTHERM model represented in Fig. 1 corresponds to the initial configuration of the rectifier operating in 110V (critical case in terms of power dissipation) exposed to 60°C. In Figure 1, the fan is indicated as 1, heat sinks (2), transformers (3), heat source components (4), exhaust grids (5 and 5a) and capacitors (6).
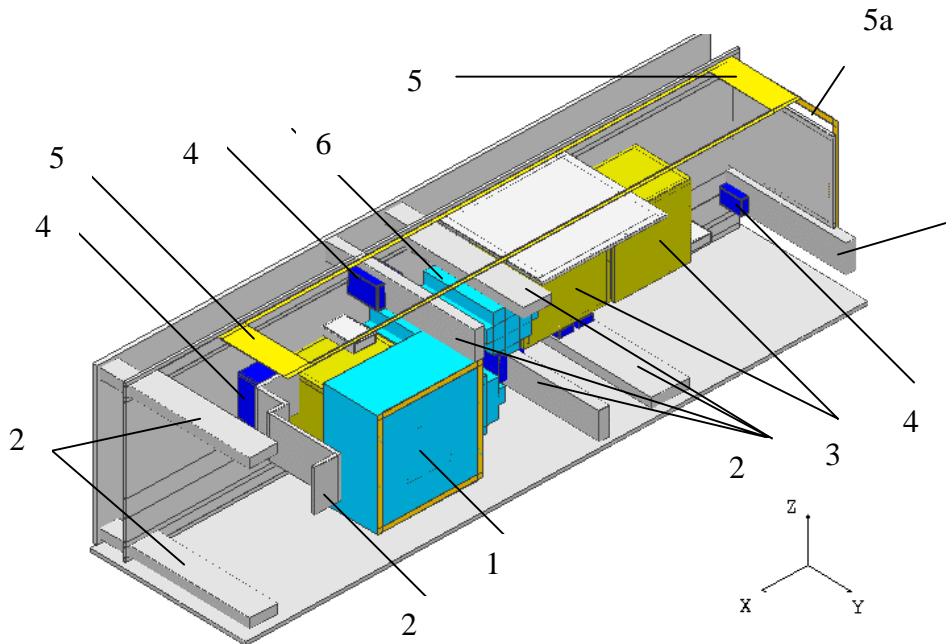

Figure 1: Thermal model of the rectifier original configuration.

In the modeling task only the most representative components, in terms of size and power dissipated, have been considered. For the sake of time consuming in the simulations, only one module was considered.

Preliminary results, shown in Fig. 2, indicate the occurrence of high temperatures (around $135\,^{\circ}$C) that might cause malfunctions (Telebras, 1996).
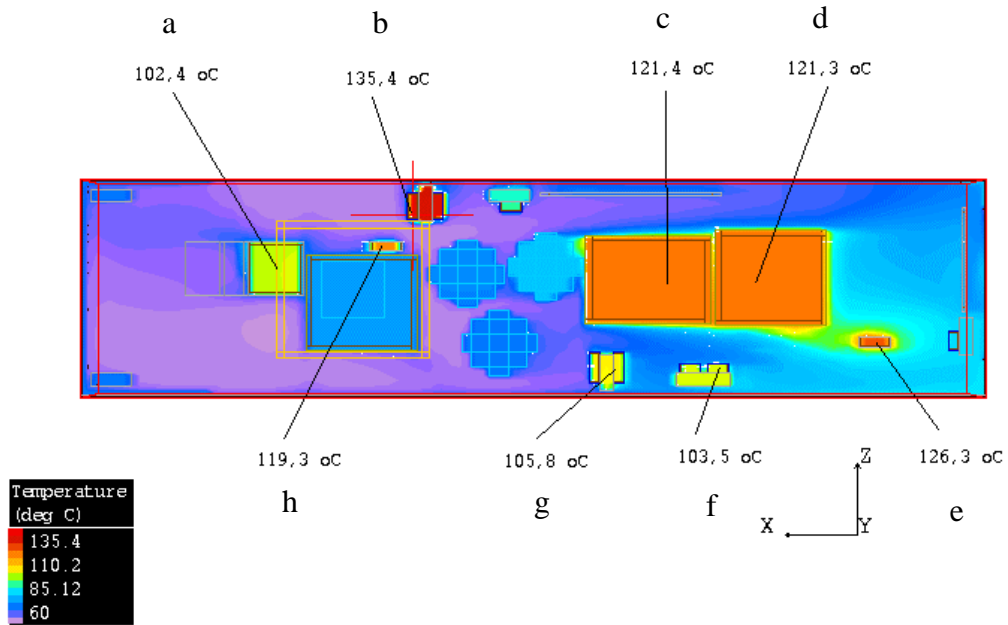
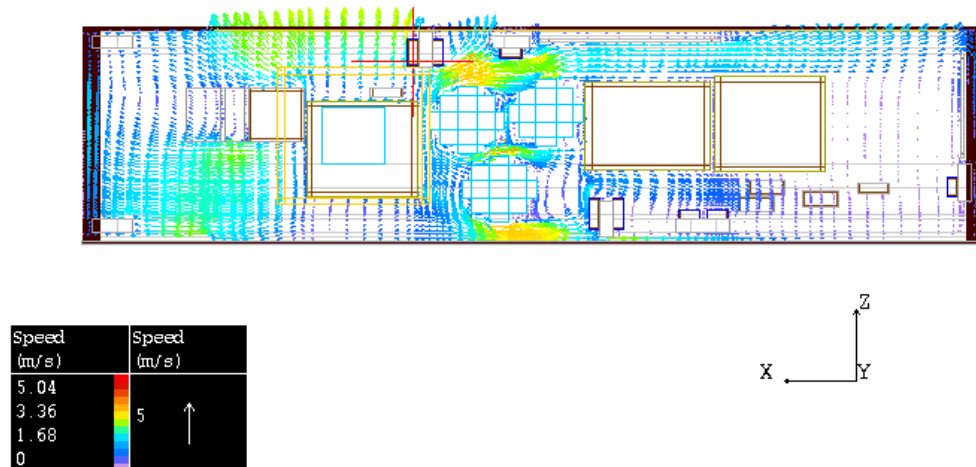Figure 2: Temperature field (plane xz); original configuration.

Figure 3: Velocity field (plane xz) for the original configuration.

The velocity field, shown in Fig. 3, helps to investigate the air ventilated around those critical components.
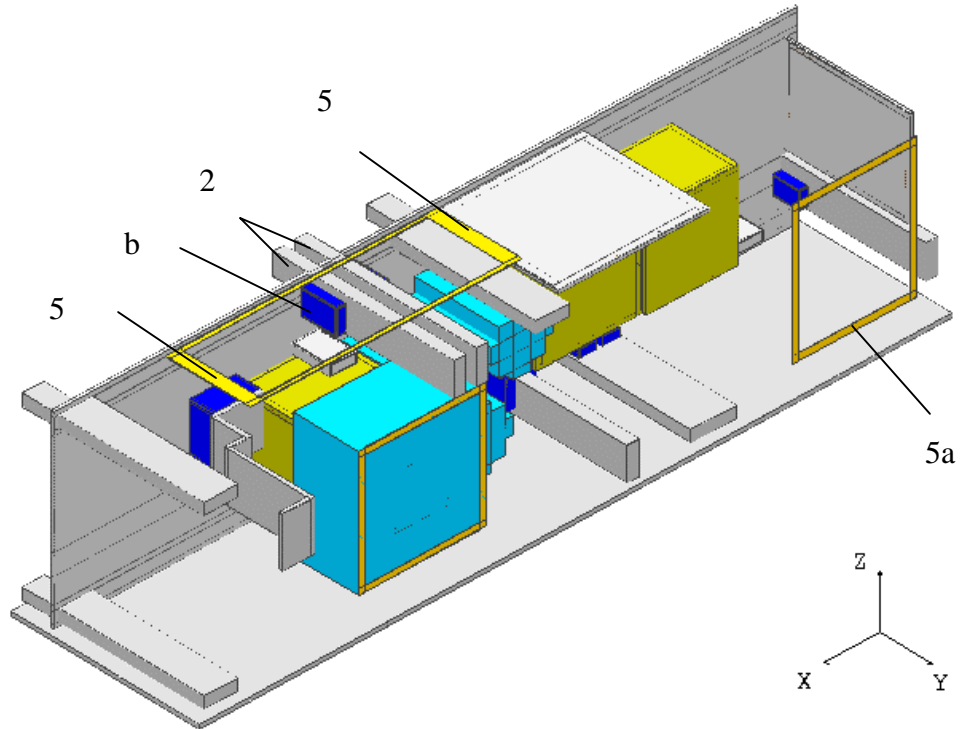
Figure 4: Thermal model of the rectifier; alternative configuration.

Modifications were proposed in the original configuration, observed in Fig. 4, including the following points:

- The change of the exhaust grid position (5a), which was formerly placed on the right boundary, as shown in Figure 1, to the right of the frontal boundary;
- The replacement of the fan by another one with better performance curve (and same dimensions);
- The adoption of two independent heat sinks of copper (2), instead of just one of duralumin, in the component b, which has the highest temperature (135,4 $^{\circ}$C);
- Reduction of the exhausting grid on the top (5), in order to increase the flow circulation and the heat exchanging through the unit.

Results achieved with the latest model are shown in Figures 5 and 6, respectively, for the temperature and velocity field in xz plane. In Fig. 5, one can observe that the changes improved the heat dissipation in the critical components (106,2 $^{\circ}$C).
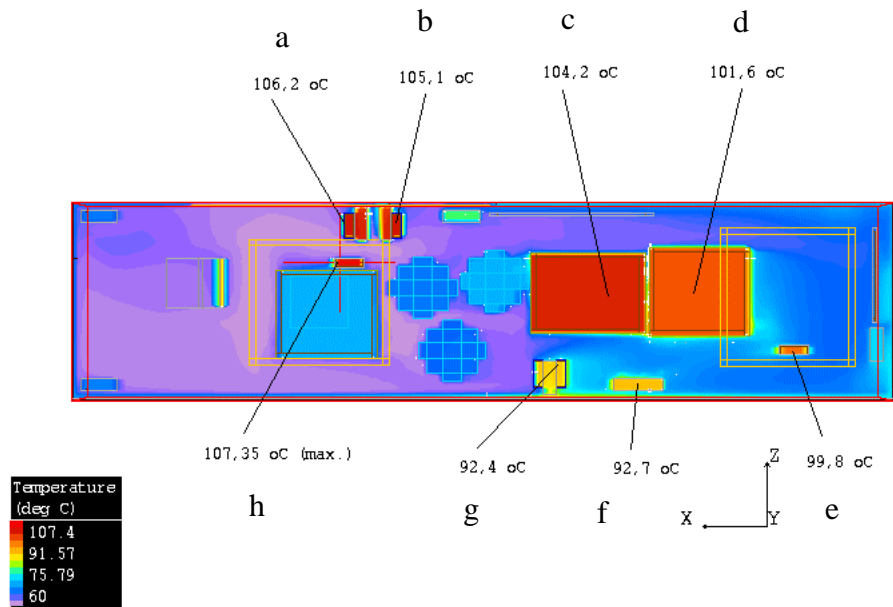
Figure 5: Temperature distribution (plane xz) for the alternative configuration.

In general, the temperature levels observed in the remaining components decreased, demonstrating that the modifications in the geometry, such as the reduction of the exhausting grid improved the ventilation through the rectifier (Fig. 6). This behavior can be noticed comparing the velocity vectors displayed at the top boundaries in Fig. 3 and Fig. 6.
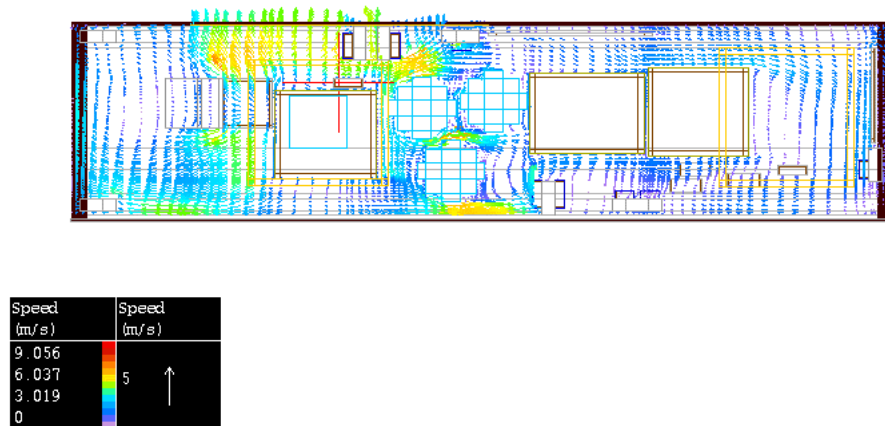

Figure 6: Velocity distribution (plane xz) for the alternative configuration.

As a result, such adjustments provoked the temperature decrement in the hottest component (b) in about 22%. Regarding the same component, the employment of a copper heat sink (which presents a better thermal conductivity) instead of duralumin have also helped the heat conduction between the heat sink and the component itself.
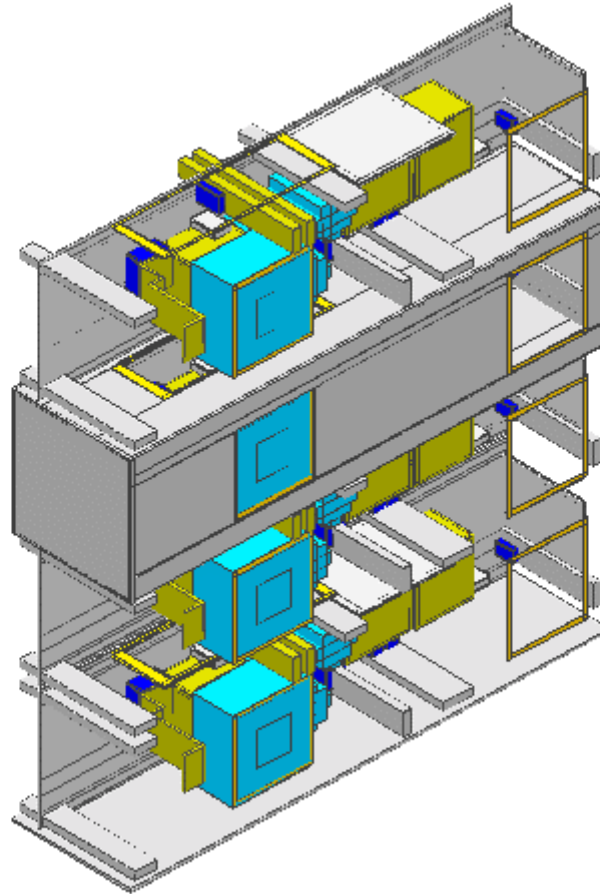

Figure 7: Model representation of a four modules rectifier.

In addition, smaller temperatures were registered at the right portion of the module, reflecting the modification of the exhausting grid position at right boundary, improved the convection heat transfer in that area. The best result for temperature decrement in that area was evaluated in 21%, for the component e, placed far at right. Figure 7 represents a four modules rectifier configuration.

Results for the proposed configuration with three modules are represented in Figures 8 and 9, where it can observed the behavior of temperature (Fig. 8) and the air flux through all modules (Fig.9). Numerical simulations, performed with four modules, have shown results very close to those achieved with the three modules system.
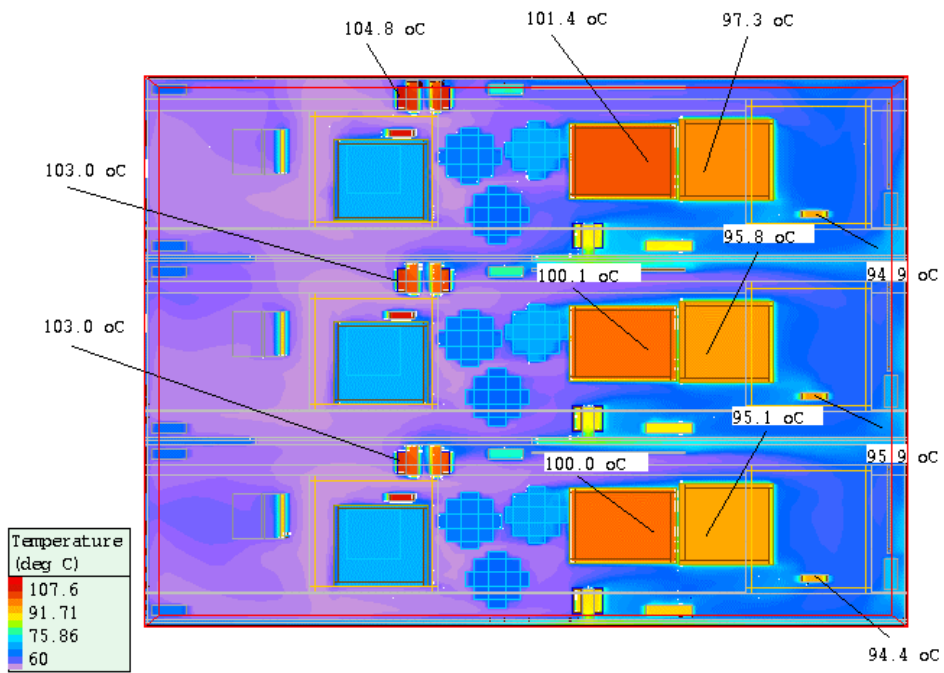
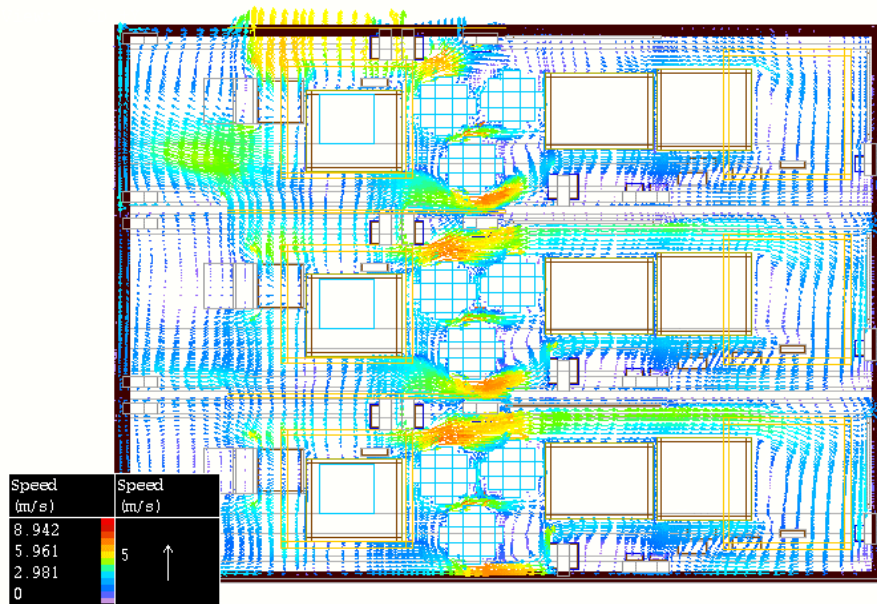Figure 8: Temperature distribution in the three modules rectifier.

Figure 9: Velocity distribution in the three modules rectifier.

5. CONCLUDING REMARKS

A thermal simulation of a digital rectifier has been performed. A thermal model in three dimensions have been constructed, using a CFD software. Preliminary results identified critical regions represented by high temperatures and deficient air circulation. Numerical experiments with alternative models were performed to reduce the overall temperature and improve the ventilation rates in the critical areas.

Among the benefits of using a CFD code in design of cooling electronics are the possibility of create a model, proceed a solution in less time and investigate several "what if" situations.

Acknowledgements

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