THERMAL ASPECTS RELATED TO POWER RECTIFIERS

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INTRODUCTION

Taking into account the thermal phenomena complexity for power semiconductor devices it is very difficult to study the heating processes both in steady-state or transitory operating conditions, using the traditional analytical equations. It is important to achieve an efficient tradeoff between the necessary accuracy, required simulation speed and feasibility of parameter determination, [1]. Approaches to simulate these processes have already been made in earlier work. Numerical programs based on the method of finite differences are proposed in [2], or based on formulation of charge carrier transport equations, [3]. A physical model using the application of continuity equation for description of the carrier transport in the low doped layer of structures is proposed in [4]. A simple calculation procedure for the time course of silicon equivalent temperature in power semiconductor components based on the previously calculated current loading is shown in [5]. In order to take into account the nonlinear thermal properties of materials a reduction method based on the Ritz vector and Kirchoff transformation is proposed in [6]. The work described in [7] outlines a model which combines the temperature dependent electrical characteristics of the device with its thermal response. The most papers are based on the thermal RC networks which use the PSPICE software, [8, 11].

1. TRANSIENT THERMAL SIMULATION OF POWER SEMICONDUCTORS

Extremely short overloads of the type that occur under surge or fault conditions, are limited to a few cycles in duration. Here the junction temperature exceeds its maximum rating and all operational parameters are severely affected. However the low transient thermal impedance offered by the device in this region of operation, is often sufficient to handle the power that is dissipated.

A transient thermal calculation is very complex and difficult to do. So, a more exactly and efficiently thermal calculation of power semiconductors at different types of input power, can be done with the help of PSPICE software.

Further on, it presents the waveforms of input powers and junction temperatures of power semiconductors within single-phase semicontrolled bridge rectifier. It has been considered a power rectifier made by SITRA AUTOMAZIONE, Alessandria, Italy, with the following parameters: rated frequency, f = 50Hz; line voltage supply, V_{sLL} = 230V; secondary inductance, L_s = 0.18mH; secondary resistance, R_s = 60mΩ; load resistance, R_{load} = 2Ω; resistance of load inductance, R_L = 0.7Ω. The parameters which could be varied were the load inductance and the firing angle. Using PSPICE software, it has been done a parametric simulation which outlines the influence of firing angle and inductance values upon temperature waveforms. On ordinate axis, the measurement unit in the case of input power waveforms, is the watt, and in the case of temperatures, the measurement unit is the ^{0}C, unlike the volt measurement unit that appears on graphics. This apparent unconcordance between measurement units is because thermal phenomena have been simulated using electrical circuit analogy. Also, P_1, P_2 and P_3 mean input powers and T_1, T_2 and T_3 temperatures, respectively.

It has been done a parametric simulation both at firing angle variation of thyristors from semicontrolled bridge rectifier, figure 1 and figure 2, and at load inductance variation, figure 3 and figure 4. It can be observed the variation of input power values that depend on load inductance variation, figure 3. The increasing of inductance value, from 0.1mH to 50mH, leads to not only input power values decreasing, $P_3 < P_2 < P_1$, but also its shape changing. The same thing can be observed at firing angle variation. So, its increasing from 60 to 120^0 el., leads to decreasing of input power values $P_3 < P_2 < P_1$, and also the changing of input power shape, figure 11. Also, the increasing of load inductance leads to decreasing of temperature values, $T_3 < T_2 < T_1$, as shown in figure 1.

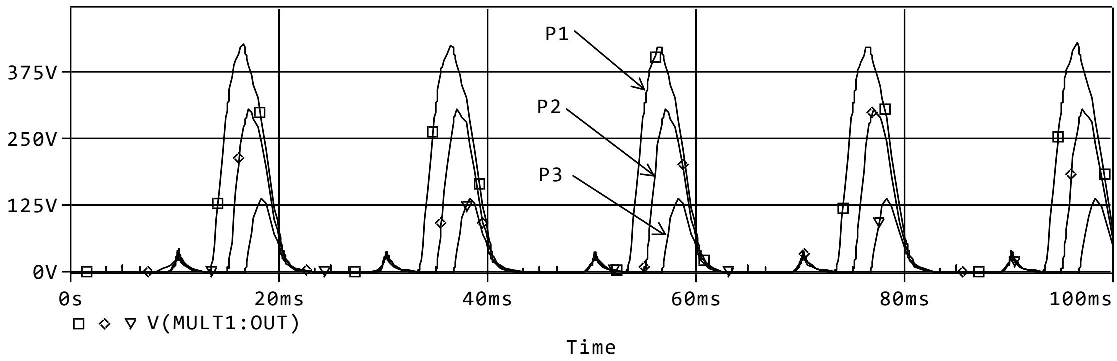

Figure 1. Input power waveforms at firing angle variation with 60, 90, 120^0 el.

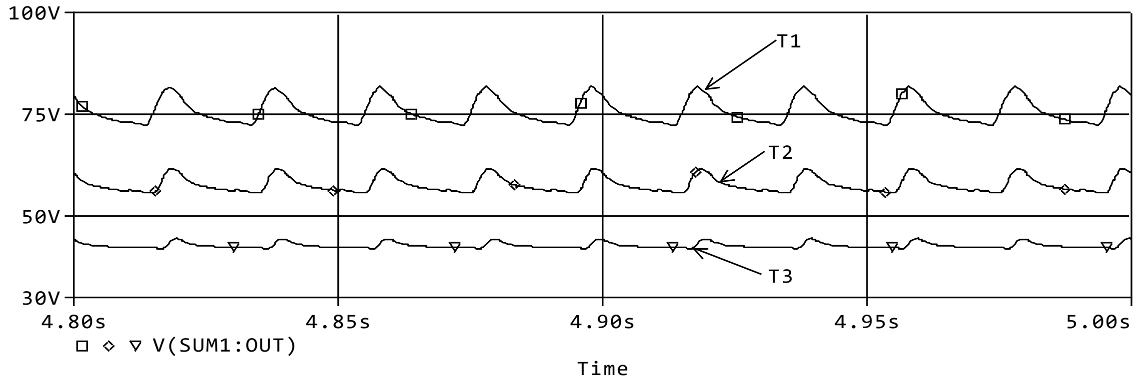

Figure 2. Temperature waveforms at firing angle variation with 60, 90, 120^0 el.

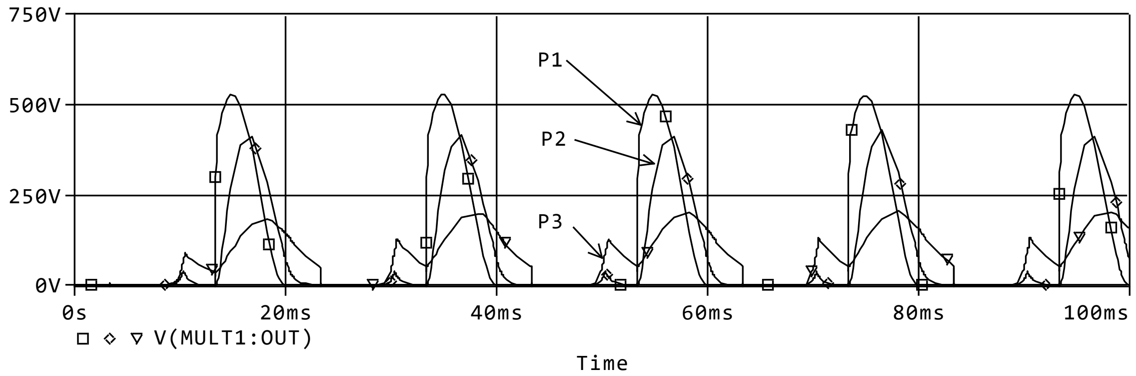

Figure 3. Input power waveforms at load inductance variation with 0.1, 10, 50mH.

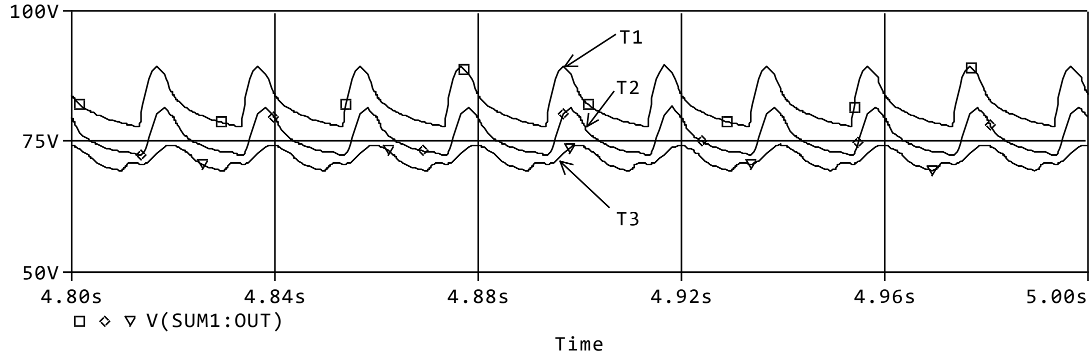

Figure 4. Temperature waveforms at load inductance variation with 0.1, 10, 50mH.

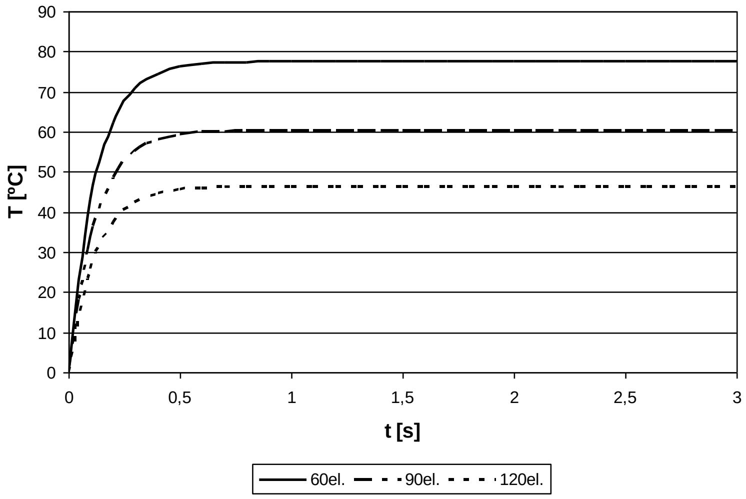

Figure 5. Temperature rise at firing angle variation.

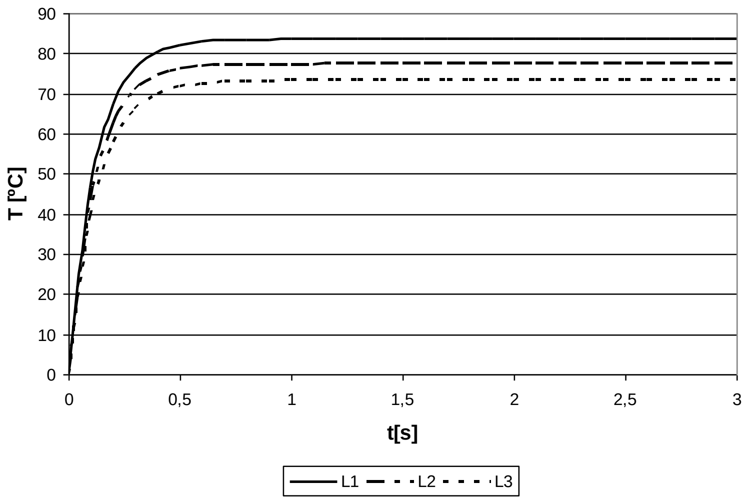

Figure 6. Temperature rise at load inductance variation.

Also, from the above simulations it has been obtained the time variation of the junction temperatures in the case of firing angle variation with 60, 90 and 120^0 el., as shown in figure 5, and for load inductance variation with 0.1, 10 and 50mH, figure 6. The ordinate axis represent temperature rise for both cases.

In order to validate the thermal simulations some measurements have been done. It was recorded the temperature rise on the case of the thyristors used for semi-controlled power rectifier. The temperatures have been measured using proper iron-constantan thermocouples fixed on the case of power semiconductor devices. The measurements have been done both for the firing angle values of 60, 90 and 120^0 el., and load inductance values of 0.1, 10 and 50mH.

The results are shown in figures 7 and 8. In both cases, at firing angle and load inductance variation, it can be noticed closer values among simulation results and measurements. Of course, there are different temperature values resulted from experimental tests (60el.exp, 90el.exp and 120el.exp from figure 17 and L1exp, L2exp, L3exp as shown in figure 18) with respect to simulations (60el.sim, 90el.sim and 120el.sim from figure 7 and L1sim, L2sim, L3sim as in figure 8), because of measurement errors, thermal model simplifications and mounting test conditions. Anyway, the maximum difference between experimental and simulation results is less than 3ºC.

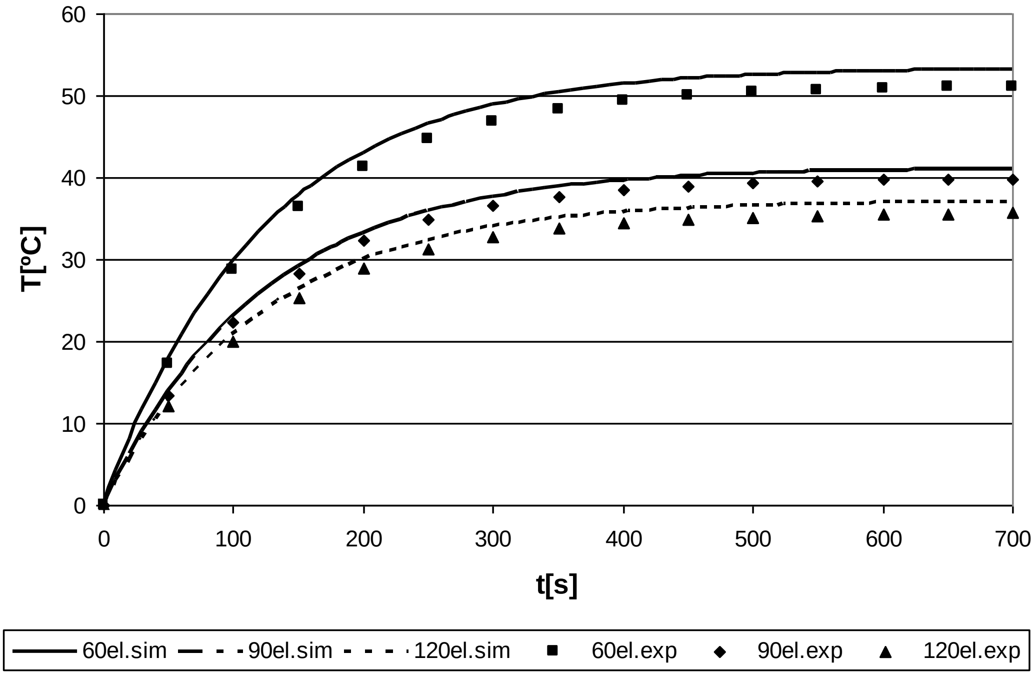

Figure 7. Comparison between simulation and experimental temperature rise of the case at firing angle variation.

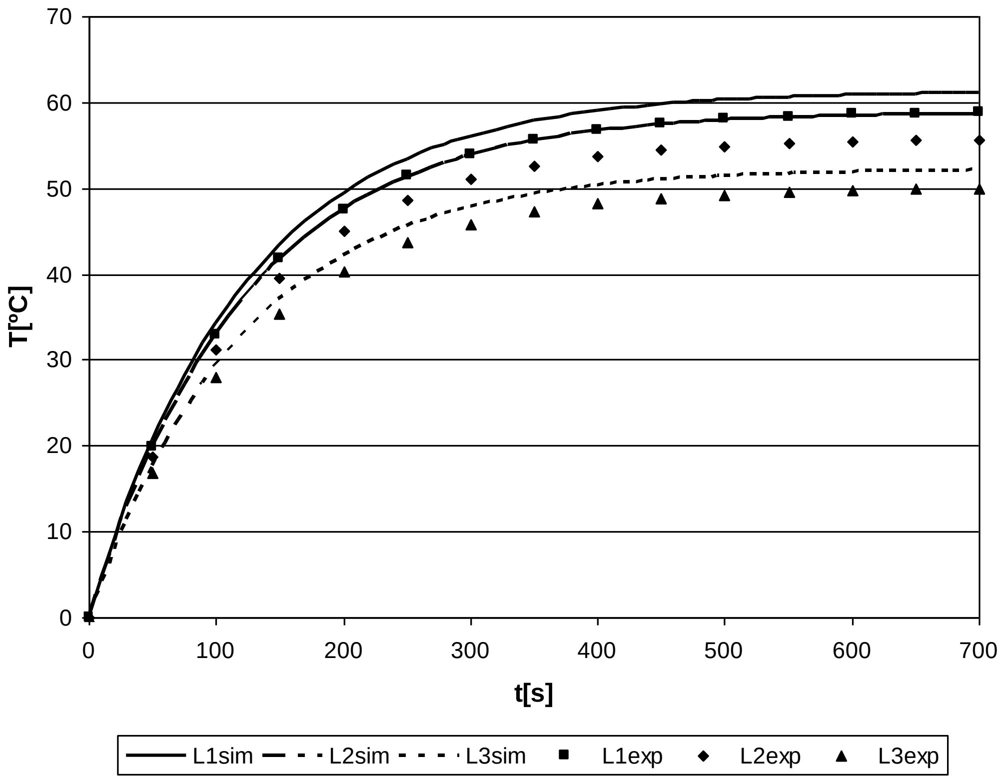

Figure 8. Comparison between simulation and experimental temperature rise of the case at inductance load variation.

2. CONCLUSIONS

From all previous graphics which have been done using PSPICE software simulation and experimental tests, the following conclusions about transient thermal evolution of power semiconductor devices can be outlined:

- the shape of input power and temperatures evolution depend on load type, its value and firing angle in the case of power semicontrolled rectifiers;
- increasing of load inductance value leads to decreasing of input power and temperature values;
- in the case of steady state thermal conditions, the temperature variation is not so important at big values of load inductance and firing angle;
- at big values of firing angle it can be noticed a decreasing of input power values and temperatures;
- there is a good correlation between simulation results and experimental tests.

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