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# PSPICE SIMULATIONS FOR SINGLE-PHASE RECTIFIERS FOR TESTING DC FUSES

# PSPICE SIMULACIJE ZA ENOFAZNE USMERNIKE ZA TESTIRANJE DC VAROVALK

Adrian Plesca[1], Costica Nituca[1], Gabriel Chiriac[1ℜ], Zhiyuan Liu[2], Yingsan Geng[2]

**Keywords:** Power Rectifiers, Simulation, PSpice, DC fuse

## Abstract

In this article, simulations were realized for different power rectifiers used for testing DC fuses. Using the OrCAD PSpice software, a single-phase uncontrolled bridge rectifier and a single-phase controlled bridge rectifier are simulated for different loads. From the data analysis, some important conclusions were realized regarding the form of the temperature waveforms in transient conditions and quasi-steady state thermal conditions.

## Povzetek

V tem članku so bile izvedene simulacije za različne usmernike moči, ki se uporabljajo za preskušanje enosmernih varovalk. S programsko opremo OrCAD PSpice se simulirajo enofazni nenadzorovani mostni usmernik in enofazni mostični usmernik za različne obremenitve. Iz analize podatkov je bilo ugotovljenih nekaj pomembnih zaključkov glede oblike temperaturnih valov v prehodnih pogojih.

ℜ Corresponding author: Ph.D. Gabriel Chiriac, Tel.: +04 0727 645058, Mailing address: Bd. Dimitrie Mangeron, nr. 21- 23, 700050 IASI, Romania, E-mail address: gchiriac@tuiasi.ro

[1] 1 Technical University "Gheorghe Asachi" from Iasi, Faculty of Electrical Engineering, Bd. Dimitrie Mangeron, nr. 21- 23, 700050 IASI, Romania

[2] Xi'an Jiaotong University, Department of Electrical Engineering, 28 Xianning W Rd, JiaoDa ShangYe JieQu, Beilin Qu, Xian Shi, Shaanxi Sheng, China.

# 1 INTRODUCTION

Considered to be simple and well-known devices after more than a century of research and development, certain phenomena of fuses' operating are not totally known and understood. The construction of the fuses, their components, geometry, and basic operation are well known and described in the bibliography *[1, 2, 3]*. The main components are the fusible and the quenching medium with the role of overcurrent protection and disconnection of the electric arc that forms in the fuse, respectively. A very important aspect is to convey the heat developed into the fuse during its protection operating. In the case of normal operating mode, the energy due to the Joule effect into the fuse link is released to the surrounding medium, and a thermal balance is established. In the case of high amplitude overload, the fuse holds more energy than can be released, increasing the internal temperature *[4-10]*.

Utilization of the DC fuses are expanding due to development of photovoltaic plants, electric vehicles, and DC microgrids, but in the case of Direct Current, the cutting-off of short-circuit current by using fuses is more difficult *[11, 12].* The existing protection in the DC section of the photovoltaic plant consists of fuses that are not sufficient to protect against over-current due to their slow reaction *[13]*. Some studies compare how adding fuses to the DC link affects the operating times of fuses and the total energy in the circuit *[14, 15].* Thus, testing the DC fuses becomes important for a large domain *[16].* In this aspect, it is considered that the semiconductor devices are to support different types of stresses, including mechanical, thermal, electrical, environment and incident radiations, with effects in their operating and reliability *[17-19]*.

In this article, using the OrCAD PSpice software, different simulations were realized, highlighting the differences between the waveforms in the case of the variation of some elements of the power rectifiers used for testing DC fuses. A single-phase uncontrolled bridge rectifier and a single-phase controlled bridge rectifier are considered for the simulations.

# 2 THERMAL ASPECTS OF POWER SEMICONDUCTOR DEVICES

The operation of the power semiconductor devices in different working conditions, both steady-state and transient, is accompanied by the heating of the device due to the dissipated power.

The simplest situation is the heating by a rectangular pulse power. In the case of power pulses with other waveforms, the heating estimation can be achieved by having an approximation with the rectangular pulses. The periodical power pulses can be replaced with rectangular pulses. A more exact estimation of the diode heating in the case of certain power pulses can be realized with OrCAD PSpice software.

Therefore, simulations and their analysis are considered using OrCAD PSpice software for two types of single phase bridge rectifiers, which can be used in a fuse test bench (uncontrolled and controlled rectifiers).

Waveforms of the power pulses and of the junction temperatures are presented as elements of power rectifiers. The waveforms of the temperatures in the case of the quasi-stationary regime as also considered from the thermal point of view.

The unit of measurement for the power pulses waveforms is the Watt (considered for Y-axis), and for the temperatures is the Celsius degree, in contrast to the unit of measure Volt, which is presented on the graphs. This is because the thermal aspects were modelled for electrical circuits, and the specialized software preserves the units of measure of the electrical units.

P1, P2, and P3 denote the power pulses corresponding to the variation of the important parameters, while T1, T2, and T3 represent the temperatures, respectively.

## 3 PSPICE SIMULATIONS FOR THE SINGLE-PHASE UNCONTROLLED BRIDGE RECTIFIER

The variation of the power pulse waveforms P1, P2, and P3, depends on the variation of the resistive load. Thus, with increasing of the loads, the amplitude of the impulse will decrease, which implies a decreasing of the amplitudes of the junction temperatures T1, T2, and T3, and a decreasing of the temperature variation.

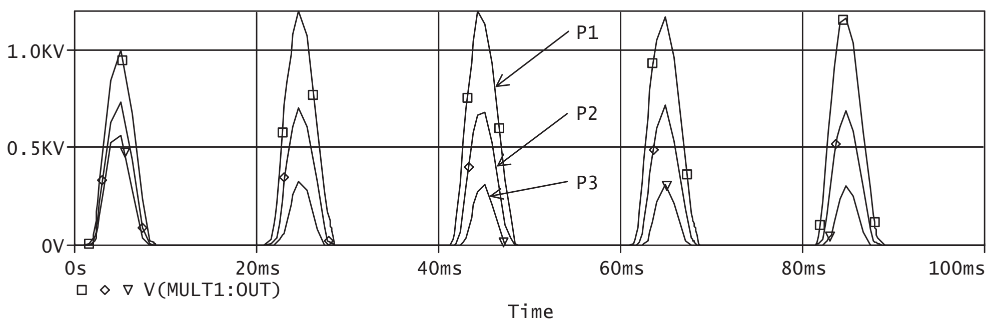


***Figure 1:*** *Input power waveforms at load resistance variation with 10, 20, 50Ω*

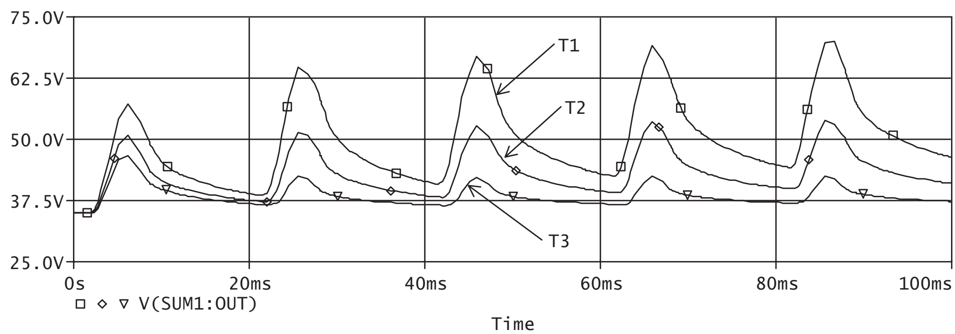


***Figure 2:*** *Temperature waveforms of thermal transient conditions at load variation with 10, 20, 50Ω*

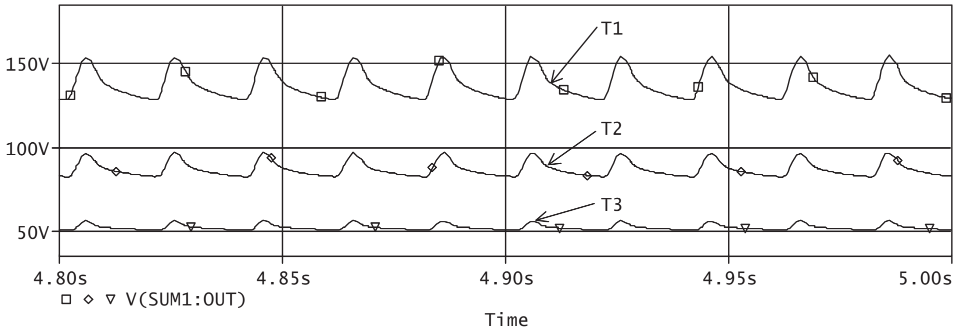


***Figure 3:*** *Temperature waveforms of quasi-steady state thermal conditions at load variation with 10, 20, 50Ω*

In the quasi-stabilized regime, it can be seen that the differences between the temperatures corresponding to the values of the resistive load are increasing, but the temperature variation shapes and the tendency of the apparition of the thermal stabilized regime are maintained. The variation in time for the amplitudes of the temperatures is low. It is also seen, for the quasi-stabilized regime, that the maximum value of the T1 temperature, corresponding for a resistive load of 10Ω, surpasses the maximum admissible value for the junction, which is 125℃. Thus, there some protection measures or the increasing of the load are necessary, as in the case of the T2 and T3 temperatures.

## 4 PSPICE SIMULATIONS FOR THE SINGLE-PHASE CONTROLLED BRIDGE RECTIFIER

A simulation was realized considering the firing angle variation for the thyristors. It is observed that, as the firing angle increases, the power pulse decreased, and, thus, so does the temperature amplitude. The quasi-stabilized regime highlights the differences between the temperature amplitudes for the considered cases.

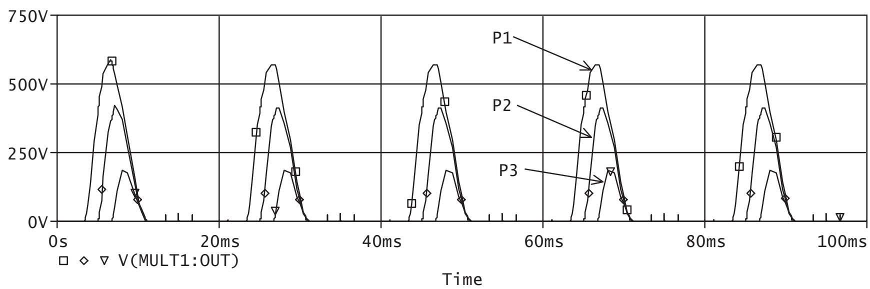


***Figure 7:*** *Input power waveforms at firing angle variation with 60, 90, 120° el*

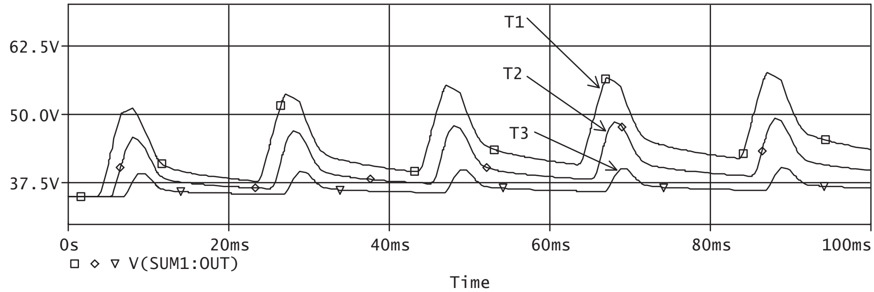


***Figure 8:*** *Temperature waveforms of thermal transient conditions at firing angle variation with 60, 90, 120° el*

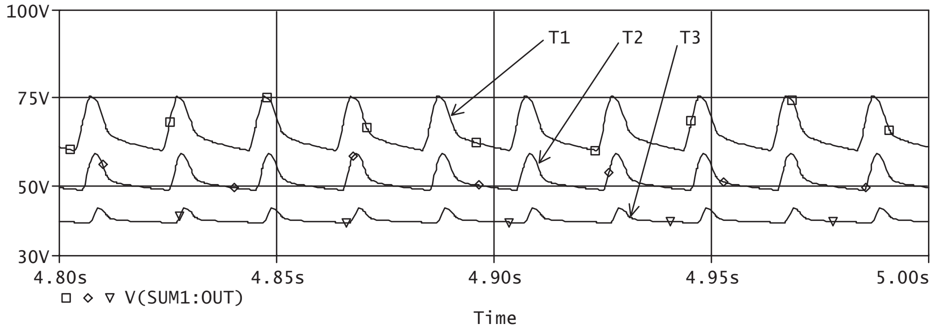


***Figure 9:*** *Temperature waveforms of quasi-steady state thermal conditions at firing angle variation with 60, 90, 120° el*

# 5 CONCLUSIONS

From the above OrCAD PSpice simulations, some conclusions can be made:

- The power impulse form, and thus the form of the corresponding temperature signals, depends on the load type and value, and on the control angle for the controlled rectifiers;
- With the increasing of the load value (both resistive or inductive ones), a decreasing of the power pulse and a decreasing of the temperature values can be observed;
- In a quasi-stabilized regime the variation of the temperature is much lower at high values of the load, both for resistive or inductive loads;
- In the case of the controlled rectifiers, at high values of the control angle, a decrease of the power pulses is observed, with results in decreasing of the temperature values; in the case of the quasi-stabilized regime, the variation of the temperatures is also lower compared to the case of the low control angle values.

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