ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2003, Tome I, Fascicole 3

ANALYZING OF SWITCHING PROPERTIES OF IGBT TRANSISTOR USING PSCAD-EMTDC SIMULATION PROGRAM

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ABSTRACT

In this paper is presented functioning of the IGBT transistor in switching process, being presented mathematical model for those two stages, on and off. Based on this model result on equivalent scheme of IGBT transistor, which is tested with PSCAD-EMTDC simulation program.

KEYWORDS
transistor IGBT, simulation, switching

1. INTRODUCTION

The IGBT Transistor is an integrat monolithic structure, which contains, in Darlington connexion, a bipolar transistor and a MOSFET one, which need a simple command and which has a reduced value of the voltage drop collector-emitter in conduction at saturation. The duration of getting into conduction of the IGBT corresponds to the time necessary for getting into conduction of the bipolar transistor, and its blocking is made in a longer time than the one of a separate bipolar transistor, because the charge stocked in the base's junction is eliminated more slower.

The speed of cancelling the current is reduced and is similar with the one of the collector current from an usual bipolar transistor, when the base is open (the MOSFET transistorul is blocked long before the bipolar transistor).

2. WORK'S PRESENTATION

In this work is studied the funcitioning of the transistor into a simple circuit fed from a continuous voltage source, having a RL charge circuit. I tis achieved a mathematic model of the collector-emitter junction for the IGBT transistor in the commutation process in the two situations: blocking in conduction at saturation and, in revers, from saturation to blocking.

In fig. 1.a. is shown the electric diagram of a simple circuit with IGBT and in fig. 1.b the equivalent electric diagram of the circuit shown in fig. 1.a.

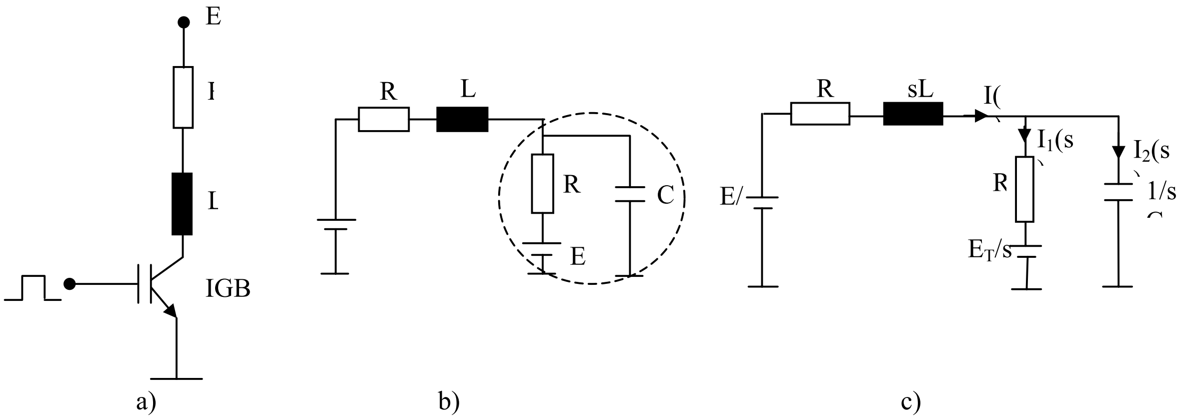


Fig. 1

In order to determine the current through the circuit, will be used the Laplace transformation method, in fig. 1.c, being presented the equivalent electric diagram of the circuit in operational.

The equation for I(s) is obtained by solving the equation system (1).

$$\begin{cases} \dfrac{E}{s} = (R + sL)I(s) + I_1(s) \cdot R_1 + \dfrac{E_T}{s} \\ \dfrac{E}{s} = (R + sL)I(s) + I_2(s) \cdot \dfrac{1}{sC} \\ I(s) = I_1(s) + I_2(s) \end{cases} \tag{1}$$

For I(s) results the following equation:

$$I(s) = \frac{E - E_T}{s[(R + sL)(1 + sR_1C) + R_1]} + \frac{ER_1C}{(R + sL)(1 + sR_1C) + R_1} \tag{2}$$

Ex. numerical:

$$I = \frac{399.3}{s\,(0.000010\,s^2 + 0.10100\,s + 20)} + \frac{0.04000}{0.000010\,s^2 + 0.10100\,s + 20}$$

Using the MATHCAD programming menu, is obtained the equation (3) for the expression of the current in real field.

$$i(t) = 399.3000000 \left(1. + e^{\left(-\frac{0.5000000000(1. + 100.\, R\, C)\, t}{R\, C}\right)} \left(-1.\cosh\left(\frac{0.5000000000\, t\, \sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C}}{R\, C}\right) - \frac{1.\,(1. + 100.\, R\, C)\sinh\left(\frac{0.5000000000\, t\, \sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C}}{R\, C}\right)}{\sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C}} \right) \right) \Big/ (10. + R) + 400.\, R\, C \left(- \frac{10.\, e^{\left(-\frac{0.5000000000(\sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C} + 1. + 100.\, R\, C)\, t}{R\, C}\right)}}{\sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C}} + \frac{10.\, e^{\left(-\frac{0.5000000000(1. + 100.\, R\, C - 1.\sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C})\, t}{R\, C}\right)}}{\sqrt{1. - 200.\, R\, C + 10000.\, R^2\, C^2 - 40.\, R^2\, C}} \right) \quad (3)$$

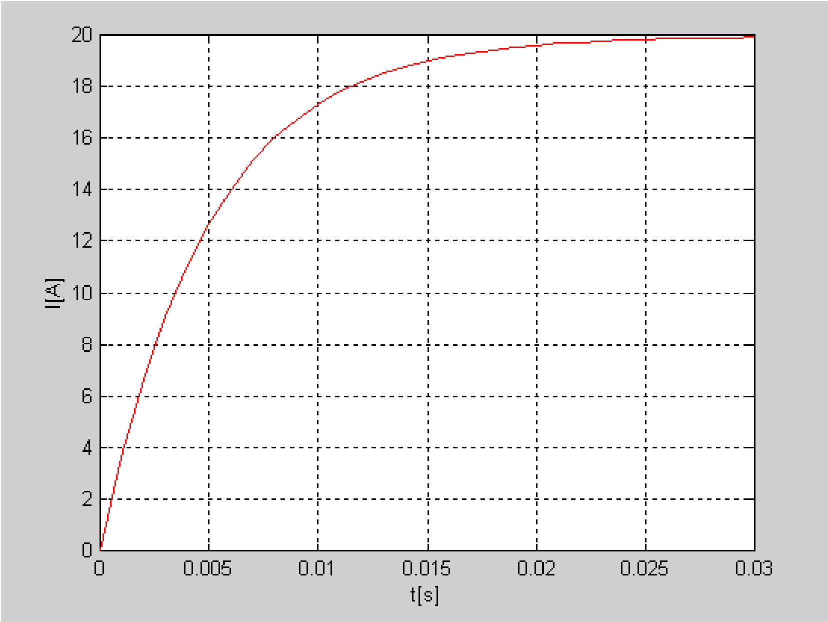
For R=10Ω, C=10^{-8}F,

$$i(t) = 19.96500000 + 19.96500000\, e^{(-5050.\, t)} (-1.\cosh(4847.937706\, t) - 1.041680052\sinh(4847.937706\, t)) - 0.4125465552\, e^{(-9897.937705 t)} + 0.4125465552\, e^{(-202.0622940 t)}$$

By using a program written in Matlab, will be drawn the graphic of the current shape for the values considered in the situation of switching from blocking to conduction, following to repeat the procedure for the switching situation in reverse.

In fig. 2.a, is shown the variation form of the current at the switching blocked-saturated and in fig. 2.b the variation form of the current for the switching saturated-blocked.

The obtained results will be compared with the wave shapes obtained in an identical circuit with the one presented in fig. 1 and achieved by simulation with the PSCAD EMTDC program.



a)

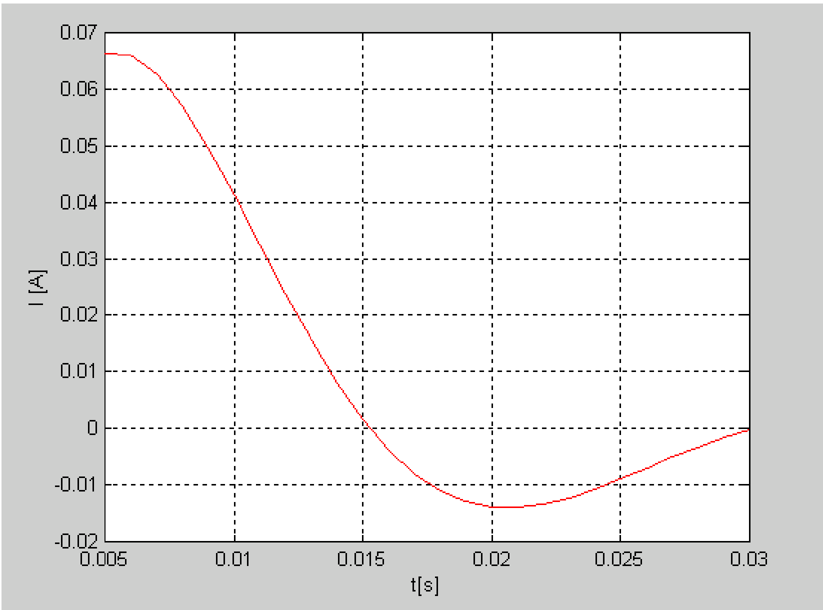


Fig.2 b)

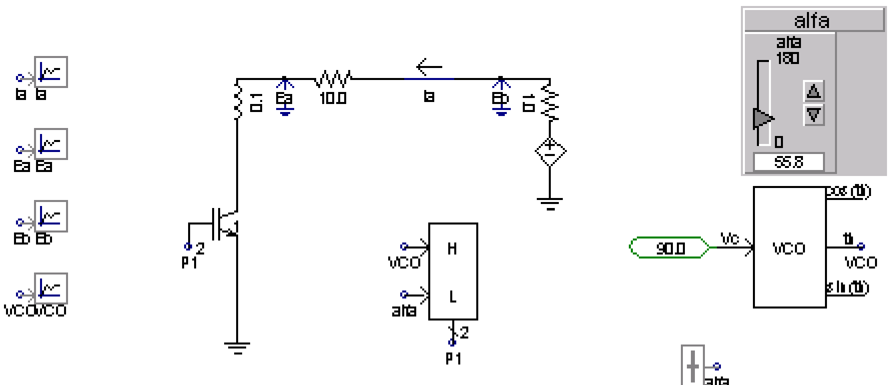


Fig.3 a)

In fig. 3.a is shown the circuit achieved in PSCAD EMTDC and in fig. 3.b. the wave shape which is corresponding to the curent through the circuit.

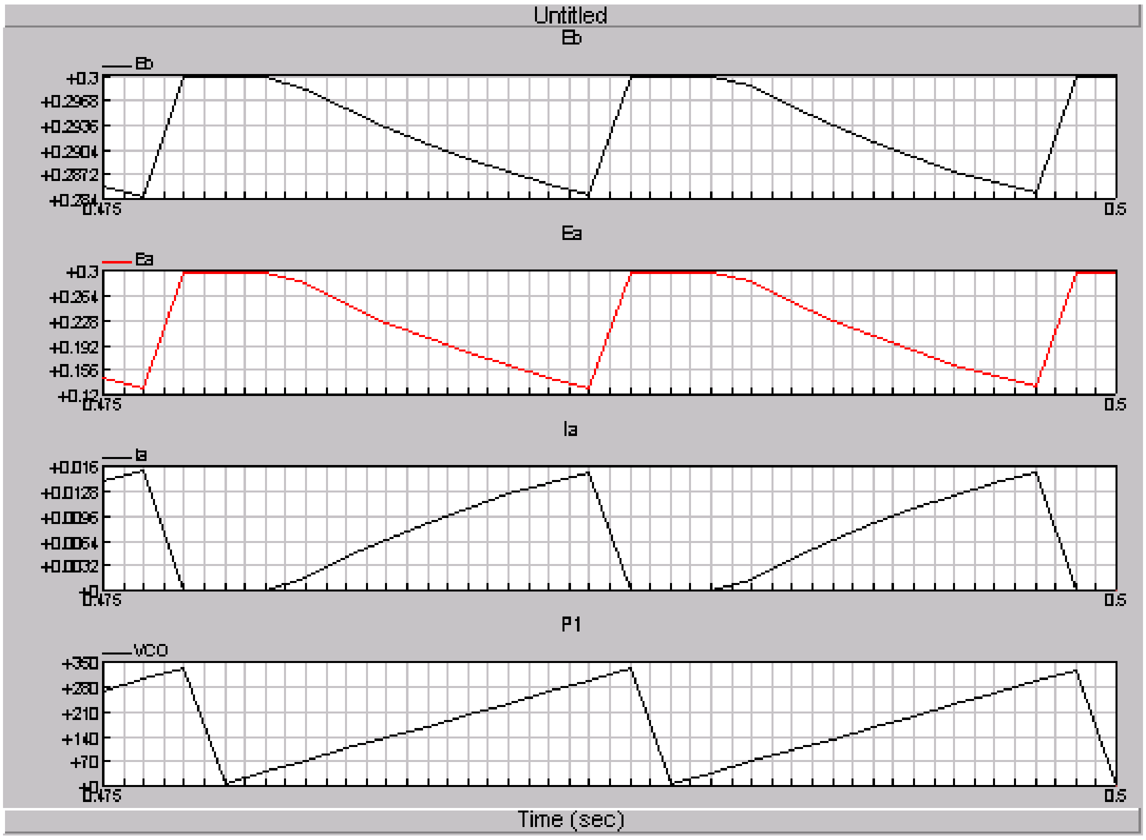
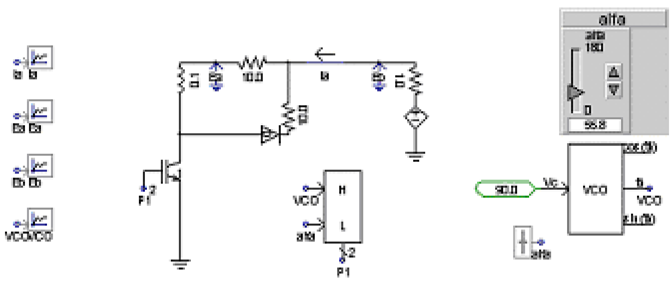


Fig.3 b)

From the analysis of the two graphics, we find a longer time for the switching to blocking, which imposes that in the current's circuit to be provided some protection circuits, especially to strongly inductive charges. The protection effect which is connected on the transistor can be seen on the graphic from fig. 4 and in the mathematic model the protection circuit is found included in the value of the capacitor from the equivalent electric diagram.

It can be seen a similarity of the two situations concerning the shape of the current in the case of the proposed equivalent circuit and in the one resulted by simulation with the PSCAD EMTDC program.



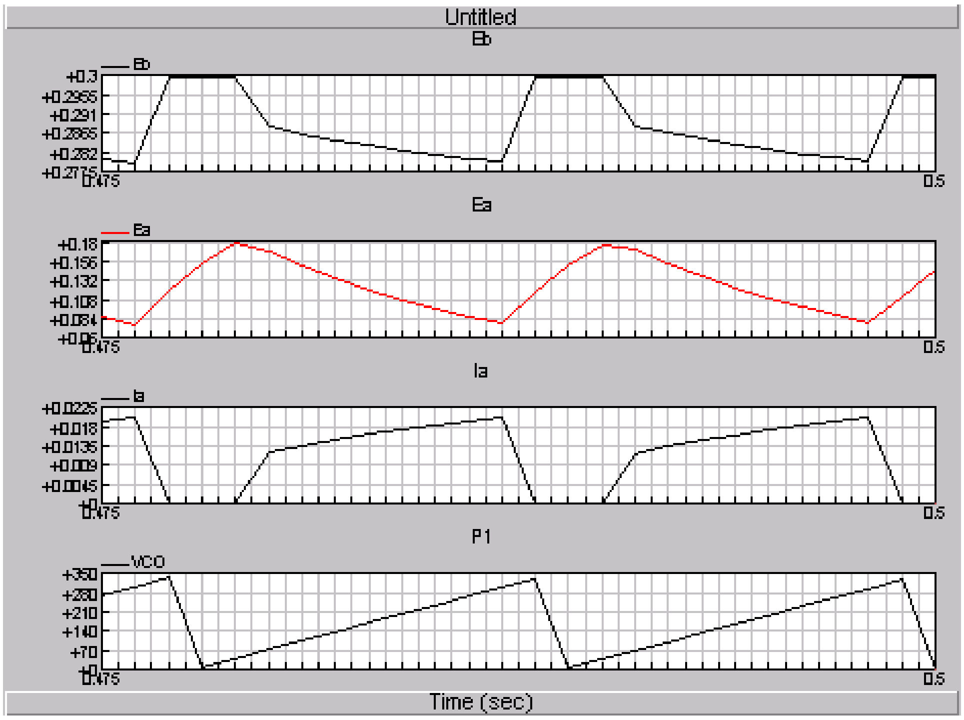


Fig.4

CONCLUSIONS:

Analysis of the functioning of the IGBT transistor monitors its behavior only in the power part, without studying also its effect on the control circuit.

The proposed mathematic model approximates quite well the behavior in switching of the transistor, emphasizing the delay especially at blocking, the effect being more pronounced as the collector current is higher, or the charge circuit's inductance de sarcină has a higher value.

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