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NUMERICAL SIMULATION OF TRANSIENT CHARACTERISTICS OF POWER IGBT DEVICE AND A STUDY ON ITS SHORT CIRCUIT

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Abstract

In recent years, a new power semiconductor switching device called the Insulated Gate Bipolar Transistor (IGBT) has been widely used in new power electronics application which are: adjustable speed motor drives, appliance controls and robotics/ numerical controls and it's was the most commercially advanced devices. The challenge of simulation in power electronics was to predict and understand the global behavior of various topologies of devices. For years, this fact could be observed in microelectronics whereas in power electronics simulation has mostly been restricted to system design.

The aim of this paper is to present a new power IGBT model and simulation of its electrical characteristics showing short computing time and reasonable accuracy. The main purpose of this paper is to point out some mechanisms relating the high current operation, which can be identified from the physical description of the IGBT. It is also important to emphasize the fact, that different types of short circuit situations will lead to different response and stress the IGBT in different way. Thus, our work is provided to modeling and simulation the short circuit phenomenon in hacheur mounting circuit based for IGBTs. Last these can present destruction risks of the converter. In order to forecast these risks and envisage solutions for its elimination, the simulation is necessary. Comparison between measurements and simulation shows good agreement in transient and steady state behavior.

Keywords: Modeling, Simulation, IGBT, Commutation, short–Circuit

1, Introduction

With the increasing acceptance of the IGBT as a new power switching device in both discrete and integrated power circuit for various power electronics application, the importance of simulation in the research and the ever increasing calculation power of computers allows representing more accurately the device.

The aim of this work is to get an IGBT model, which simulates its switching waveforms with adequate accuracy and reasonable computing time. The model has to be uses friendly.

Moreover, a complete power electronic circuit (hacheur mounting) has been investigated in order to simulate the different short-circuit situations (during blocking and conducting phase) which lead to stress the IGBT in different way, using two-dimensional numerical simulator Pspice.

2, IGBT Model

Fig.1 shows the complete model of the IGBT [4,5]. The IGBT can be looked upon as a special connection of Mos and a bipolar transistor. This basic structure forms the backbone of the new IGBT model.

In this work the simulation tool Pspice and Esacap has been used for its widespread application. Esacap offers complete sub models of Mos and bipolar transistor since the available sub models in Esacap is not fitted for power electronics application, special elements have been added in order to obtain the realistic behavior. The whole model of IGBT is put into one file. The user only has to include the model file in his circuit file for a specific IGBT using the include command.

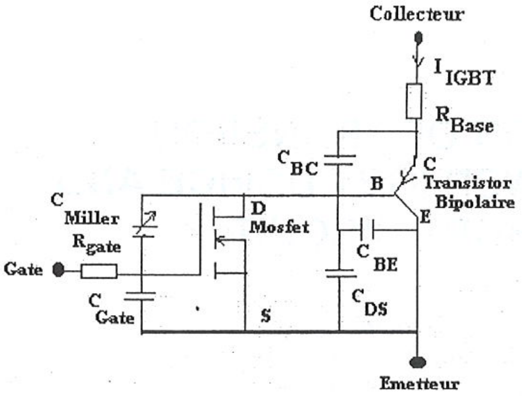

Figure 1: IGBT Model [4,8].

2.1,Steady state behavior

The calculation of the whole output characteristics are divided into two steps: modeling the IGBT in:

1.) The saturation region, where is no voltage dependence of the current.

2.) The quasi - ohmic region, where the IGBT stays during on state.

Figure 2 illustrate the simulated steady state results of IGBT.

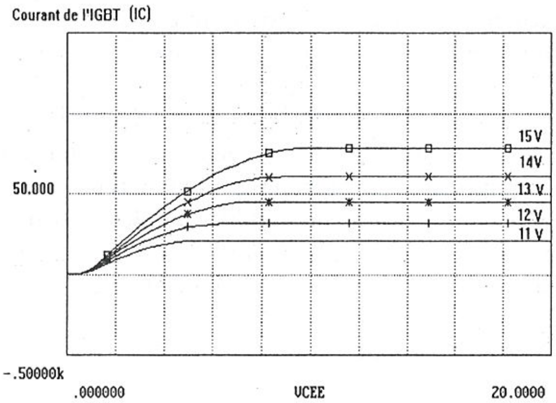

Figure 2: Simulated steady-state output Characteristics [4].

2.2, Switching performance

In this section, the parameters that govern the transition between the turn on and turn off states are analyzed.

2.2.1, Transient analyses

2.2.1.1,Turn on

The next important step is to implement the correct switching behavior. During turn-on, the Mos part of the IGBT is mainly responsible for the performance whereas the bipolar transistor influences turn-off and steady state behavior.

2.2.1.2, Turn – off

The major turn – off characteristics of an IGBT is its tail current. The form of this tail current depends strongly on the technology. The whole tail current is considered as the bipolar part of the IGBT current, the part of the current decreasing much slower than the Mos current.

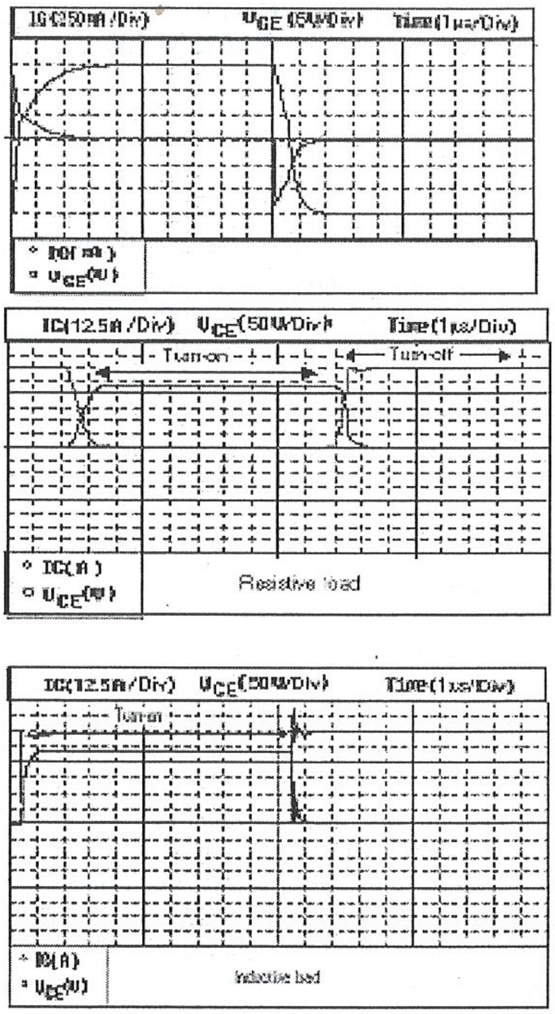

Figure 3: Simulated transient Characteristics of IGBT with resistive and inductive load.

3, dV/dt capability

In this section, our approach consist to study the capability of IGBT at turn off by using the circuit model shown in figure 4, as a result of interaction between the device and the circuit. It is necessary to consider a specific type of load for analysis, here; the inductive load is then considered because it reflects the industrial applications. The inductance Ls is the stray inductance not clamped by the diode D (freewheeling diode).

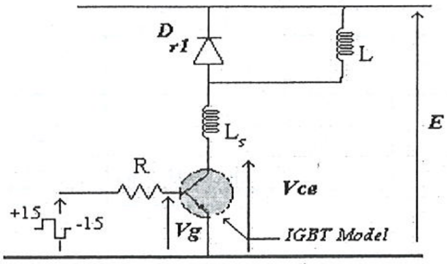

Figure 4: Inductive Switching Circuit using Power IGBT [7].

3.1, Influence of gate resistance

In this section, we will try to simulate and study the variation of (dV/dt) capability by changing gate resistance Rg and then clarify this point, which deserves more attention. Fig.5 displays the simulation results obtained at turn-off state with varying the gate resistance Rg in range of 4.5 §ظ at 1k §ظ. As can be seen from these waveforms that the (dV/dt) capability decrease with increasing gate resistance.

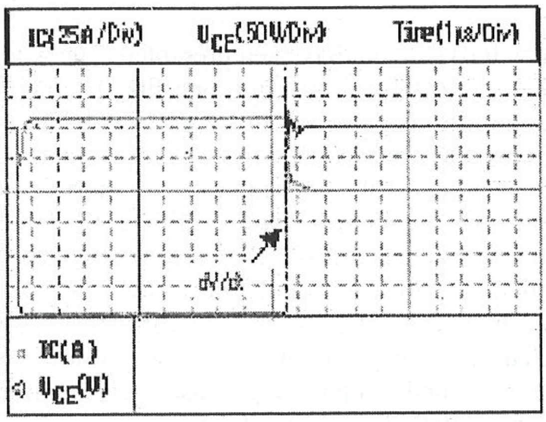

Fig.5a. Simulated transient Characteristics of IGBT with inductive load.

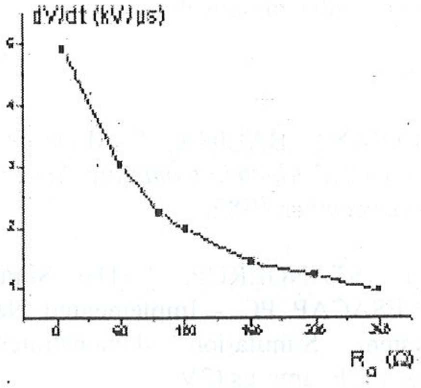

Figure 5.b: Simulated (dV/dt) values as function of gate resistance Rg.

4, Short circuit behavior

The main purpose of this paper is to point out some mechanisms relating the high current operation, which can be identified from the physical description of the IGBT. It is also important to emphasize the fact, that different types of short circuit situations will lead to different response and stress the IGBT in different way. Now two kinds of short circuit exist:

- The first is the load lack case where the IGBT is already conductor. When the failure appear, the short circuit current level correspond then and the gate voltage, which is higher than the command voltage.
- The second type of short circuit is the failure at vacuum. The load is court-circuited before that the IGBT become commanding at switch off, that is IGBT is moreover blocked.

4.1, Simulation of short circuit failure

In this paper, our study is limited to the simulation of this lacks in simple structure hacheur mounting (Chooper) at switching behavior shown in figure 6.

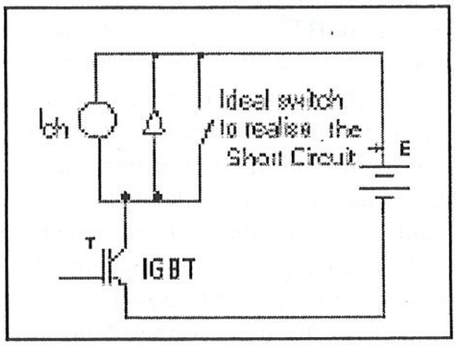

Figure 6: Hacheur Mounting for short circuit Trial [7].

The short circuit failure in this structure can appear either at blocking of this ideal switch or either at the starting of this same switch.

4.2, Results and discussion

4.2.1, Blocking case

From fig.7, we can see that during the short-circuit trial at the blocking case, the short-circuit current Icc will be high than the Ic (without short-circuit trial) approximately thrice. At the same time, a drop voltage of Vce (collector emitter voltage) will appear at moment of short-circuit trial in some hundred of nanoseconds.

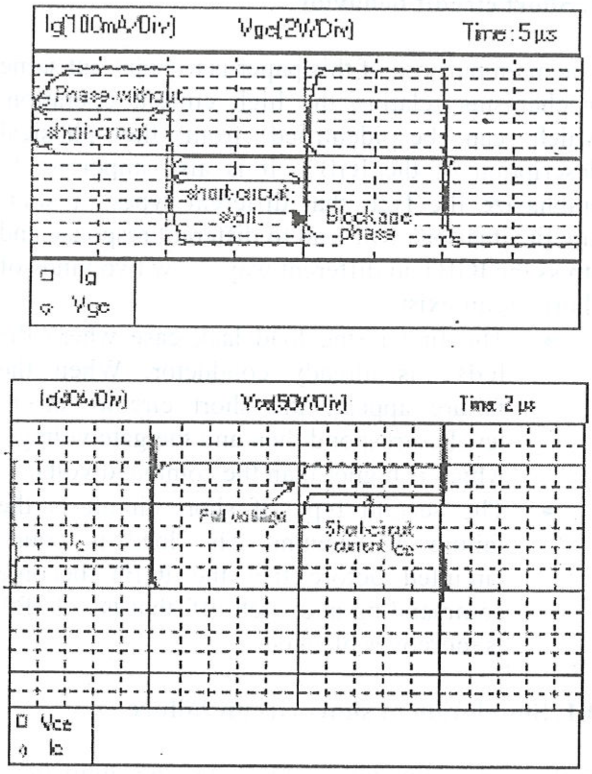

Figure 7: Short circuit failure at Blocking case.

4.2.2,Conducting case

While, if the IGBT is fully conducting when a short circuit happens, the following trip out will mean an inductive turn off at an extreme current level, for a circuit with reasonably high output impedance. If instead the output impedance is very low, the collector current level will rise very quickly and also force the collector voltage to rise with a still increasing collector current (due to the redistribution current). Moreover, the voltage really applied on the gate voltage Vge, just when the failure apparition, is higher than the generator voltage placed in the command circuit. All this will be the worst situation, resulting in the highest currents; this will result in immediate destruction of the transistor (figure 8).

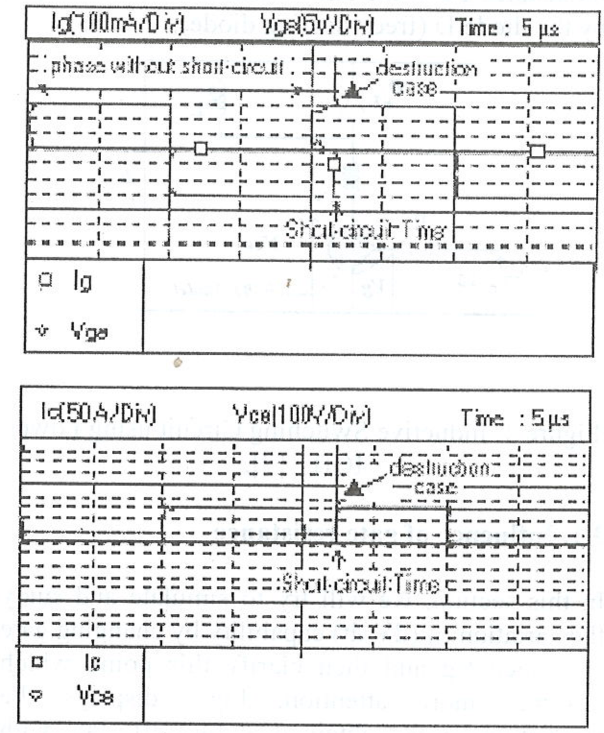

Figure 8: Short circuit failure at conducting case.

5, Conclusion

A new IGBT model has been presented. The whole model of an IGBT is put into one file. The model uses built-in features of the Pspice and Esacap. Moreover, our purpose is achieved by an improved understanding of the consequences of short-circuit situations associated with different failure mechanisms using two dimensional numerical simulator (PSPICE). Simulation results for steady state, transient behavior and in different failure mechanisms for different types of short circuit (blocking and conducting case) show good agreement with the measured data.

I hope this paper can contribute to the understanding of the (dV/dt) capability, the short-circuit failure in order to reduce cost, improved reliability and reduced parasitic.

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