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

(1)Ly. BENBAHOUCHE, (2) S.LATRECH, (3) C.GONTRAND, (1)A.SOUALEM

(1) Electronics Department, U.F.A.S, Setif, (19000), Algeria

E-mail : _Lybenbah@yahoo.fr; Fax : 00 213 36 92.51.34

(2) Electronics department, Mantouri University, Constantine, Algeria.

(3) LPM, INSA, LYON, France.

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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 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 behaviour 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. This lack of simulation application in power electronics is due to limitation in two key elements: simulation tools and models for power devices like IGBT.

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 energy conversion structure 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 behaviour.

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 the switching waveforms, a complete power electronic circuit with adequate accuracy and reasonable computing time and the short circuit failures. Moreover, the model has to be uses friendly.

2. IGBT Model

Fig.1. Shows the complete model of the IGBT[4,5].

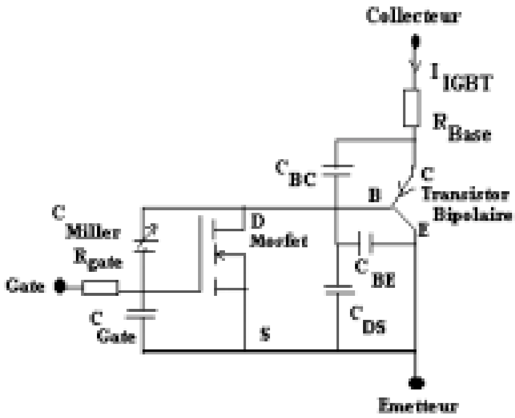

Fig.1. IGBT Model [4,5].

Pspice offers complete sub models of Mos and bipolar transistor since the available sub models in Pspice are not fitted for power electronics application special elements have been added in order to obtain the realistic behaviour. 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.

2.1. Steady state behaviour

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.

Fig.2 illustrate the simulated steady state results of IGBT.

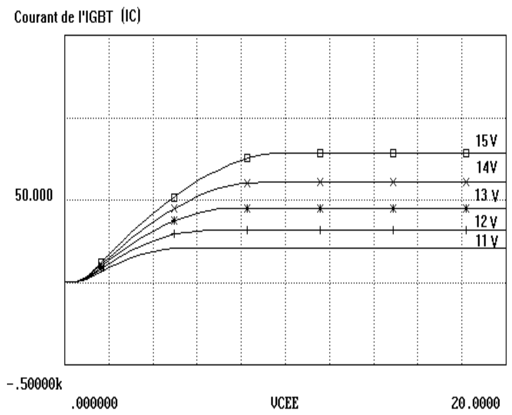

Fig2. Simulated output characteristics.[4]

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 behaviour. 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 behaviour.

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 par of the IGBT current, the part of the current decreasing much slower than the Mos current.

2.2.1.3. 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 fig.3 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 reflect the industrial applications. The inductance Ls is the stray inductance not clamped by the diode D (freewheeling diode).

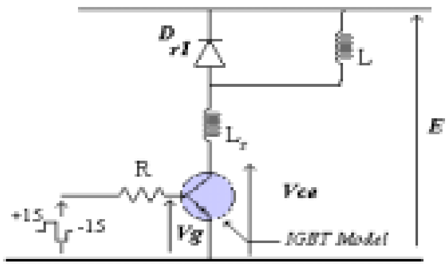

Fig.3. Inductive Switching Circuit using Power IGBT.

The composite waveforms corresponding to turn off state are shown in fig.4 and will be discussed in final paper.

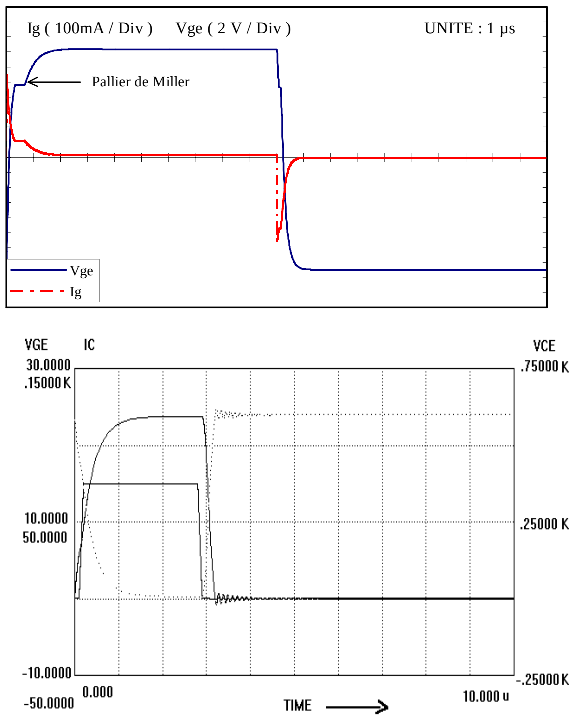

Fig.4. Simulated transient Characteristics of IGBT with inductive load [4]

3. 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.

3.1 Simulation of short circuit failure

In this paper, our study is limited to the simulation of this lacks in simple conversion structure (hacheur mounting) at switching behaviour (fig.5).

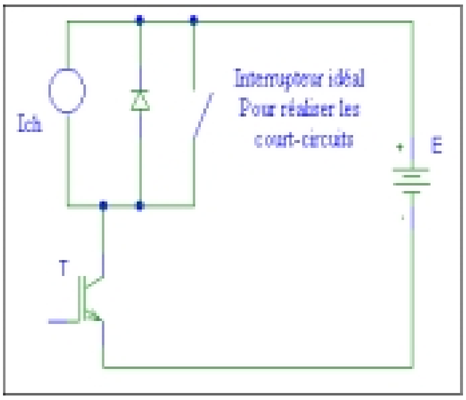

Fig.5. Hacheur Mounting for short circuit trial [4].

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. Results and discussion

During the short circuit failure at the blocking case (fig.6), the collector emitter voltage will be high (several hundred volts) in some hundred of nanoseconds. The voltage really applied on the gate, just when the failure apparition, is higher than the generator voltage placed in the command circuit.

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). This will be the worst situation, resulting in the highest currents; this will result in immediate destruction of the transistor.

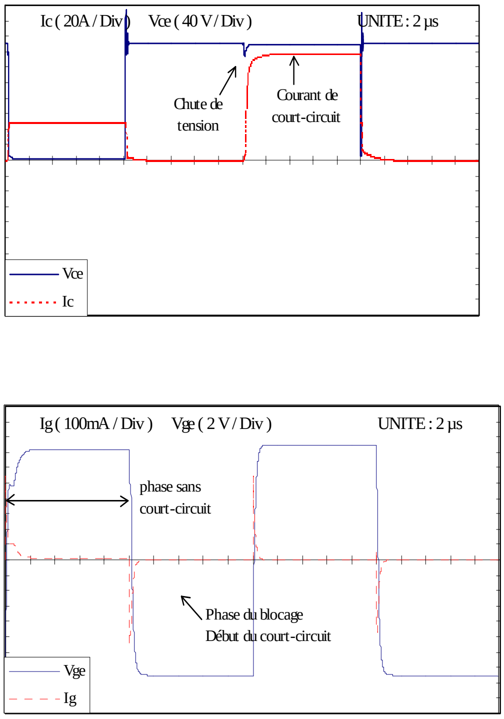

Fig.6. Short circuit failure at Turn-Off [4].

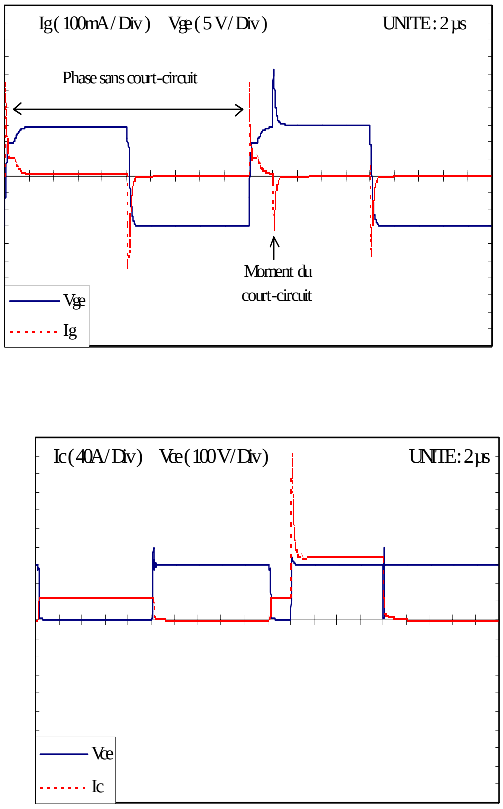

Fig. 7. Short circuit failure at Turn- On [4].

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, the model has to be use-friendly. The user only has to include the model file in the circuit file for a specific IGBT, using the include command. Simulation results for steady state, transient behavior and in different failure mechanisms for different types of short circuit, show good agreement with the measured data.

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