IGBT MODULE TECHNOLOGY: STATE OF THE ART AND FUTURE EVOLUTIONS

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Introduction

The goal of module technology was always to integrate more and more power semiconductors. It can either mean the integration of IGBT-sixpacks with single chips per leg or the integration of high power single switches, which consist of a large number of chips in parallel.

The integration of driver circuits into Power Modules suffered from drawbacks, related to different thermal characteristics between signal devices and power devices. Today the emphasis is more on an optimized system, i.e. inverter with driver and power semiconductor circuits in different packages but designed to fit mechanically and electrically.

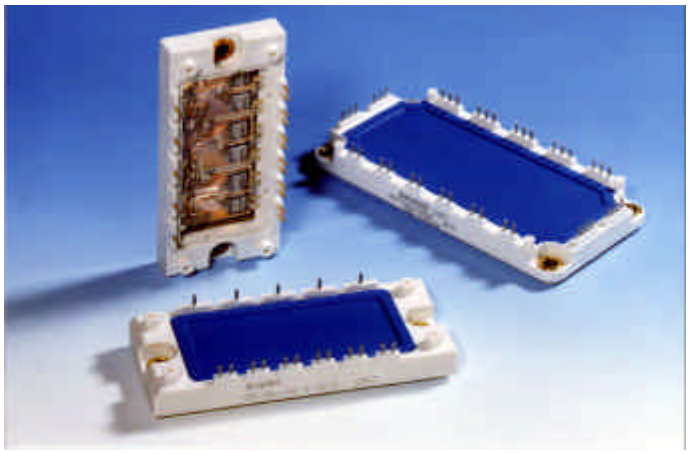

Figure 1: Econo2 and Econo3 Modules

Econopack

An excellent compact solution is represented by an inverter using Econopack Modules (**Fig.1**). Both rectifier stages, Inverter stages and other special functions like break circuits and soft starters are available in this package. The inverter design based on the Econo Modules is a „Module on Board Design“. The Econopacks have solderable pins to be soldered into a circuit board. The same may carry all other components of the inverter, as well. A common soldering process is wave soldering. It results in very cost effective manufacturing of inverters. The Econo-Modules themselves are designed to be manufactured in a simple and automated process. The number of piece parts and sizes of these modules are kept as low as possible to allow for cost effective compact inverter solutions.

Even though the Econo concept started with low current sixpacks. Today there are bigger (Econo 3) modules available, which cover the current range up to 600A and the voltage range up to 1700V. By paralleling of Econo`s on board even higher currents can be achieved.

Thermal analysis and modeling show that these power levels can be achieved on board as long as the design rules for wire bonds, solder joints and board layout are taken into consideration. For the board design it is important to spread the current and to prevent bottle necks for the current at the solder joints.

The Econo module will be extended by Power integrated Modules, which include the input rectifier bridge, the break chopper, a Temperature sensor and the IGBT inverter in one package.

All the different configurations are processed uniformly on eupec`s Econo line.

IHM, IHV

The high current range of up to 2400A and 3300V is covered by a wide range of Modules with screw terminals and sizes of up to 190mm by 140mm (IHM: IGBT High Power Modules; IHV: IGBT High Voltage Module). All of these modules have several chips in parallel. Therefore one of the key factors for the performance of these modules is the paralleling of IGBTs and diodes.

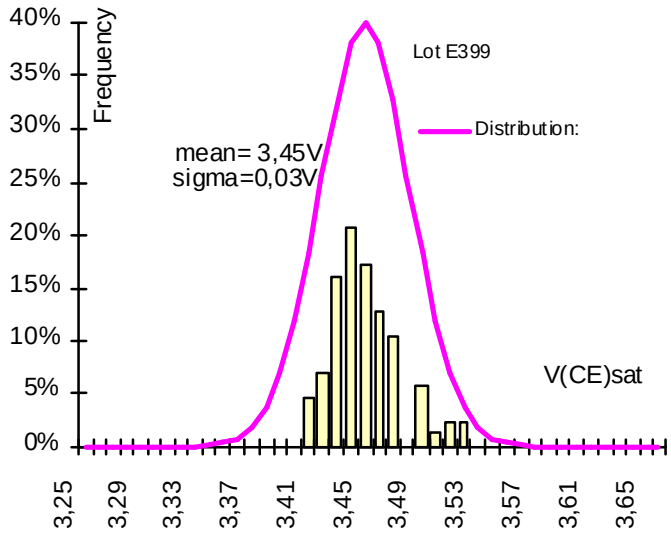

Figure 2: Distribution of V_{CEsat}-values of IGBT-chips of one lot (50 A, 3300 V) ,test conditions: T_{vj} = 25 °C, V_{GE} = 15 V, I_c = 50 A

A symmetric design of the current paths inside the module, a tight distribution in forward voltage drop (**Fig.2**) and switching characteristic is mandatory to meet this requirement. The positive Temperature Coefficient in VCEsat for the NPT-IGBT (NPT: IGBT-Technology as done by Siemens) is of great help, as well.

The design is optimized by Computer simulations of the inner RLC-network in conjunction with the Chip characteristics and the spread of electrical parameters. This leads to a controlled parallel operation.

For the thermal management of these high power ratings the base plates are especially manufactured to maintain a convex shape. The thermal interface of module to heat sink, therefore allows a tight fit and a low thermal impedance from case to sink.

Further improvements will be achieved by sectored base plates, which allow an even better attachment of the base plate to the heat sink. New materials like AlSiC will also help to improve this interface, but will also eliminate solder fatigue at the joint of substrate to base plate.

Reliability

A lot of efforts have been spent to increase the life time of wire bonds. This development was driven especially by traction applications. Due to optimization of materials and special processes in module production, the power cycling capability of wire bonds could be significantly improved. With the special processes as applied to the 3300V-IHV and 1700V-IHM`s one can say that the wire bond failures are eliminated. Results of life tests are shown in **Fig. 3.**

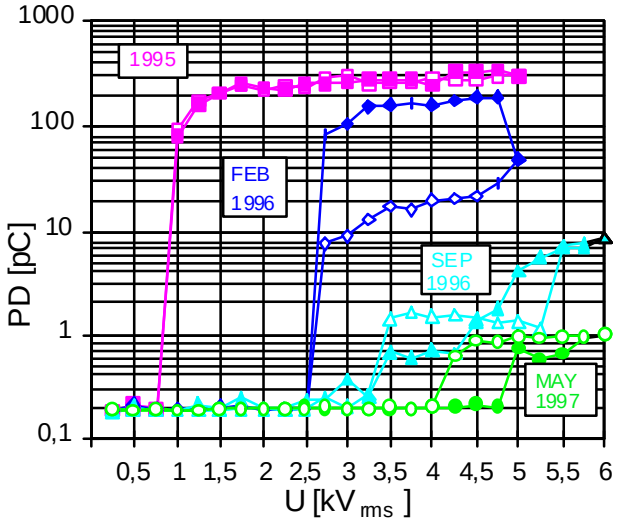

Figure 4: PD-Improvements on 3.3 kV IGBT-Modules

Another important progress was made with the insulation capability of modules. Again this development was initiated by high voltage applications (IEC 1287). By implementing a partial discharge test, a more sensitive tool to measure insulation characteristics was established. It led to the selection of new materials and processes. This results in an insulation performance up to 6kVac. The onset and offset voltages for partial discharge as well as the level of partial discharge (PD) is represented by **Fig. 4**.

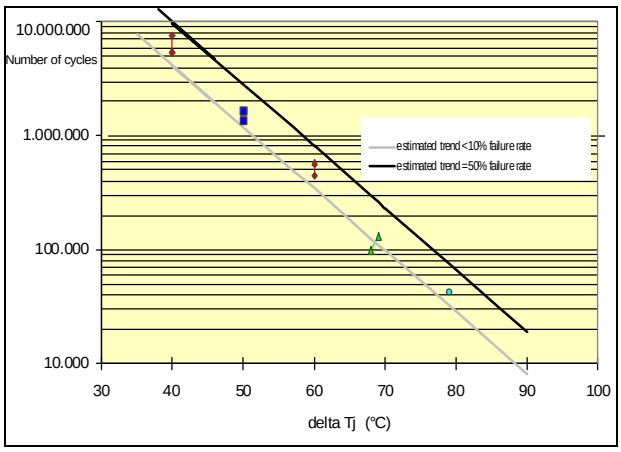

Figure. 3: Highly accelerated power cycling tests of multi-
chip high power IGBT modules (FZ1200R33KF1)

Conclusion

The module technology will be extended to cover even higher insulation levels. The processes are becoming more and more uniform and standardized. This allows us to manufacture high volume modules and special high power modules with same high quality level and experience in technology.