ECPE - The Industrial and Research Network for Power Electronics in Europe

Thomas Harder, ECPE European Center for Power Electronics, 90443 Nuremberg Germany
thomas.harder@ecpe.org, www.ecpe.org

Abstract

ECPE European Center for Power Electronics is an Industrial and Research Network for Power Electronics in Europe with focus on research, education and advanced training as well as on public relations for power electronics.

ECPE is driving precompetitive joint research in power electronics financed from an industrial research fund. Three Demonstrator Programs have been started in 2003/2004 involving leading Competence Centers in Europe. The paper gives an overview and presents first results from the ECPE Demonstrator Programs

- System Integrated Drive for Hybrid Traction in Automotive,
- Industrial Drives – System Integration,
- Power Supplies with Ultra-High Power Density.

Furthermore, ECPE has started a European initiative of academia and industry to jointly develop power electronics research and technology roadmaps. Our vision is that these longterm research roadmaps (up to 2020) will become a guideline for power electronic research directed by universities and research centers, provide an orientation for public research programs and help industry to prepare for upcoming technology steps.

I. Introduction

ECPE European Center for Power Electronics was founded in 2003 on the initiative of leading power electronics industries as an industrial and research network for power electronics in Europe. In the meantime the network comprises 20 member companies. Leading European university and research institutes are integrated in the network as so called Competence Centers.
The focus of ECPE activities is put on research, education and advanced training as well as public relations for power electronics in Europe.

Fig. 1: Industrial members of ECPE

Major achievements in the ECPE networking activities include:

– ECPE web site www.ecpe.org as networking platform,
– Seminar and workshop program with up-to-date topics in power electronics,
– Internet based Online Course on Power Electronics (with ETH Zurich),
– ECPE working groups e.g. on Power Electronics Research & Technology Roadmaps,
– Precompetitive joint research projects in power electronics.

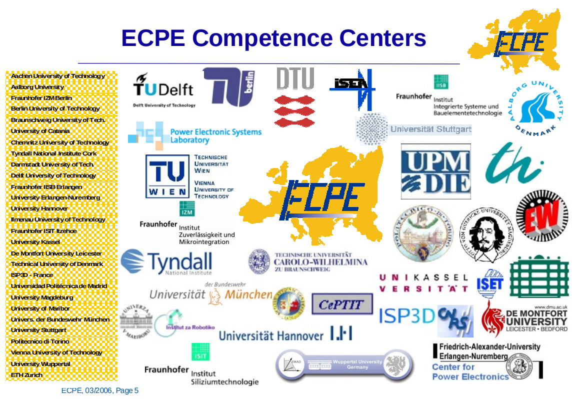

Fig. 2: University and research institutes in the ECPE Network (Competence Centers)

II. ECPE Visions and Objectives

The objective of ECPE is the promotion or research, innovation, education, publicity and technology transfer in the area of power electronics in Europe.
The main activities of ECPE are:

- Precompetitive Research on Power Electronic Systems
- Education & Advanced Training
- Public Relations and Lobbying for Power Electronics

The overall objective is to strengthen the competitive situation of European power electronic industries and users of power electronics. Improving design and production technologies in power electronics will facilitate that the focus remains in Europe.
As an industrial network, ECPE shows the importance of power electronics to the public, to increase the acceptance of the political and academic decision-makers and of students to look for a career in this area. ECPE intensifies and promotes research and development in the area of power electronics in a European competence network of research institutes coordinated by industrial partners.

Organisation and Structure of ECPE:

Apart from the registered association ECPE European Center for Power Electronics e.V., a limited company (ECPE GmbH) has been founded. The association is running the European network, whereas the company has its role in the ECPE joint research financed from a research fund of the ECPE partner companies. ECPE GmbH conducts research contracts with leading European Competence Centers - university and research institutes, monitors the research projects and holds the resulting intellectual property rights. Figure 3 shows the structure of the ECPE organisation.

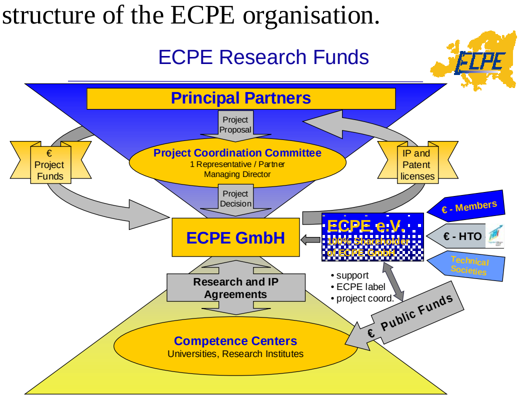

Fig. 3: ECPE structure with association (ECPE e.V.) and limited company (ECPE GmbH)

II.1 Precompetitive Joint Research

The precompetitive research in power electronic systems in ECPE is based on longterm research roadmaps, and has its focus on automotive and industrial power electronic systems.
With ECPE it could be managed for the very first time, to jointly formulate research topics in a European industrial consortium of main players in power electronics, and to push high-risk pre-competitive research with own resources.
The ECPE research activities funded by the ECPE partner industries is focussing at so-called demonstrator projects where new ambitious power electronic systems or sub-systems are developed and realized by leading European Competence Centers. A project coordination committee from the ECPE partner companies decides on the selection of project topics, some examples are the Demonstrator Projects which will be introduced in this paper:

- System Integrated Drive for Hybrid Traction in Automotive
- Industrial Drives – System Integration
- Power Supplies with Ultra-high Power Density

Apart from its own industrial joint research programme, ECPE is active in the preparation of research projects funded by the European Commission. The idea is to use the ECPE network as a pool of industrial and academic partners to form specific consortia and to drive project applications on the European level.
One example is the EC project ´High Density Power Electronics for Fuel Cell and ICE-Hybrid Electric Vehicle Powertrains (HOPE)´ which recently started in the 6th Framework Programme.

II.2. Education and Advanced Training

ECPE activities on education and advanced training include expert seminars, workshops as well as an online course for engineers in industry.
Seminar and workshop topics cover:

– Power Electronics Packaging
– Power Electronics System Integration
– Building-in Reliability into Power Electronic Systems
– Advanced Power Conversion Concepts for Motor Drives
– Power Supplies
– Renewable Energies

– SiC User Forum – Potential of SiC in Power Electronics Applications
– High Temperature Electronics and Thermal Management

The ECPE Online Course ´Power Electronics´ has been developed under licence of ETH Zurich, Power Electronic Systems Laboratory (Prof. J.W. Kolar). This training course comprises about 100 interactive and animated Java applets as well as a script on fundamentals and theory of Power Electronics.

II.3. Public Relations for Power Electronics

It is important to have ´one strong voice´ of power electronics industry to the public and to politics to create awareness for power electronics as a key and enabling technology.

III. ECPE Demonstrator Programs

ECPE is driving precompetitive joint research in power electronics financed from an industrial research fund. Three Demonstrator Programs have been started in 2003/2004 involving leading Competence Centers in Europe:

- System Integrated Drive for Hybrid Traction in Automotive,
- Industrial Drives – System Integration,
- Power Supplies with Ultra-High Power Density.

First results from the ECPE Demonstrator Programs will be presented in the following chapters.

III.1 System Integrated Drive for Hybrid Traction in Automotive

The integration of the power electronic inverter with an electrical machine in the automotive powertrain is in the focus of the automotive Demonstrator Program where the existing cooling circuit from the internal combustion engine is used also for the direct liquid cooling of the power electronics. The mechatronic integration of motor and power electronics leads to an ultra-high power density of 75 kVA/l for the inverter. The high temperature of the cooling medium of up to 115°C in combination with this high power density poses a unique challenge.

Requirements for power electronics used in the automotive powertrain:

- Coolant temperature up to 115°C
- Ambient temperature in the engine compartment up to 140°C
- High currents (several 100A)
- High voltages in the range of 200V...450V
- Very small and cleaved mounting volume
- High vibrational load
- Tough reliability requirements
- Very low cost targets

An optimised thermal design is necessary to master this thermal challenge. All temperature-sensitive components, passives and semiconductors, have to be thermally connected to the cooling system which provides a sufficient cooling capacity although working on a very high temperature level.
On the module level, the optimized thermal design has to provide a homogeneous distribution of the chip temperature of the power semiconductors.
Figure 4 shows the demonstrator integrating the electric machine as well as the power and control electronics into the clutch box of a car.

Fig. 4: Automotive demonstrator: integrated drive for hybrid traction

III.2 Industrial Drives – System Integration

Project description and objectives

The main objective of the Demonstrator Program ´Industrial Drives – System Integration´ is to significantly reduce the size of the converter of a 2.2 kW industrial drive for an asynchronous machine, compared to current commercial units. Thereby, the development of the key technologies is focused on compact design, manufacturability and costs. The project is being carried out by two Competence Centers from the ECPE network: Delft University of Technology and RWTH Aachen.

IPEM approach and 3D passive integration

The main focus of this Demonstrator Program is the development and application of integration technologies that will lead to the above miniaturization goal. We envisage that the project objectives can be met by pursuing two concepts – integration and advanced thermal management. Integration of components is a means to achieve a compact design, reduce the number of construction parts and thus decrease the cost. Advanced cooling is crucial for ensuring that, given a relatively small volume, the dissipated heat is removed efficiently so that the components operate in their allowed temperature range. We propose a hybrid integration concept where the inverter is partitioned into three sub-circuits depending on the power level and heat density. Each sub-circuit is manufactured in a suitable integration technology. These system components are referred to as Integrated Power Electronic Modules (IPEMs). We propose that the converter is broken down into the following system components:

- *Planar IPEM on a ceramic substrate:*
  This IPEM contains a ceramic substrate with the high heat density semiconductor power devices.
- *Planar IPEM in PCB*
  The electronic control circuitry, the auxiliary power supplies and the gate drive circuitry are built on a Printed Circuit Board using PCB integration technologies.
- *3D IPEM (Three dimensional Integrated Power Electronic Module)*
  This IPEM contains the large passive components of the converter such as the low pass filter and EMI filter. Compared to the previous two IPEMs that use state-of-the-art technologies, this IPEM needs new integration concepts.
- *I-Housing (Integrated convert. housing)*
  An aluminium casing that contains the three IPEMs will be forced air cooled.

The thermal management concept is based on the integrated housing that encloses the IPEMs. It serves as a heat collector and a heat sink for the three IPEMs. The overall shape and the profiling of the surfaces is designed so that the heat is removed in a way that the components of the IPEMs will operate at their desired temperatures.

Integration technologies and design concepts for 3D IPEM

In conventional drives, passive components such as low pass filters and EMI filters are constructed as assemblies of discrete components. These components are generally bulky and not designed to spatially fit with each other, which results in a large part of the converter volume being occupied by passive components and air. A large portion of the passive components assembly volume and cost is taken up by packaging parts such as housing, interconnections etc. By using bare unpackaged components that share packaging parts (such as common housing and thermal management) both volume and cost reduction could be achieved. Taking integration to even higher levels, components themselves can be integrated so that one component performs more than one function.

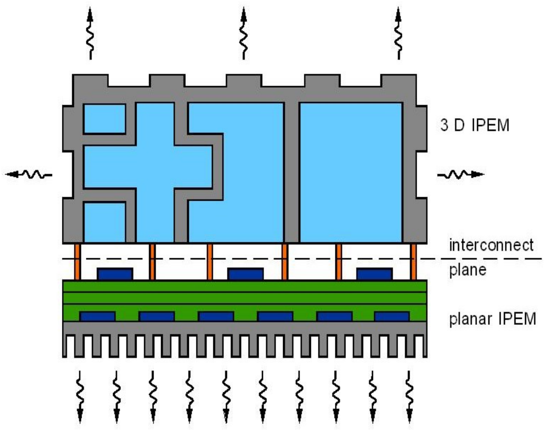

Fig. 5: Outline of the converter integration

Figure 5 shows the schematic diagram of the ´Industrial Drives´ demonstrator with the 3D integration approach for the converter.

III.3 Power Supplies with Ultra-High Power Density

The Demonstrator Program on Power Supplies aims at the development of an ultra compact isolated DC power supply with three-phase PWM rectifier front end for applications e.g. in variable speed drives, IT systems and process technology. The focus is put on the application of advanced power semiconductors, integration and cooling technologies. Apart from the improved performance (efficiency, power density, size), reliability, EMI standards and cost reduction are considered.

In the first step, a 500 kHz unity power factor, three-phase AC/DC converter has been developed with the objective to realise in hardware a 10 kW/l three-phase PWM rectifier power circuit. The next step has the further objective of implementing a 10 kW/l isolated DC/DC converter.

To achieve the high power density goal, new control techniques and power electronics technology were developed. These developments include a dedicated power module with SiC diodes, an innovative water cooler, high speed gate drivers and current sensors, a low profile ´zero-ripple´ EMI filter, and high-speed digital control. The 10 kW/l rectifier has been experimentally implemented and exhibits excellent performance, and achieves a low THD current with unity power factor over a wide operating output power range. The power supplies demonstrator is shown in figure 6.

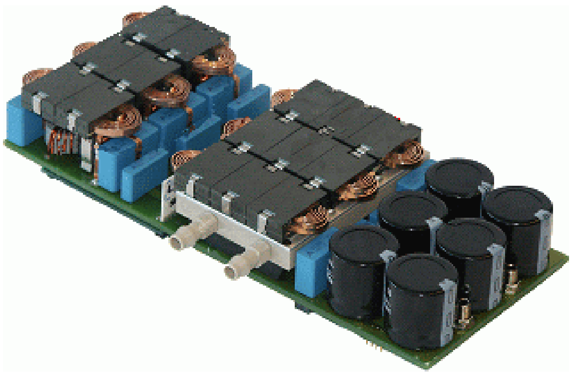

Fig. 6: Power supply with ultra-high power density

IV. Research Roadmaps

ECPE has started a European initiative of academia and industry to jointly develop power electronics research and technology roadmaps. Our vision is that these medium to longterm research roadmaps (up to 2020) will become a guideline for power electronic research directed by universities and research centers, provide an orientation for public research programs and help industry to prepare for upcoming technology steps.
The chosen approach focuses on the requirements in key applications and systems using power electronics. In single working groups experts from industry and university are working on the roadmaps in the corresponding application area.
The defined segments include

- Power grid infrastructure, power generation & distribution
- Large drives (large industry and traction drives)
- High performance motor drives
- High frequency power supplies
- High frequency power conversion (low power applications < 1 kW)
- Automotive power electronics
- Future (renewable) energy sources

V. Conclusions

With the ECPE the power electronics cluster network will achieve higher attention to meet the megatrends of future requirements. Competences of power electronics experts from academia and industry focus on mainstream research in these disciplines with the goal to strengthen this key industry in Europe.

Acknowledgement:

The set-up of the ECPE European Center for Power Electronics e.V. with the network office in Nuremberg is supported by the ´Bayerische Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie´ in the frame of the ´High Tech Offensive Bayern´ as well as by the European Union in the frame of the structural fund Ziel 2.