Short Descriptions Proceedings

Keynote: HVDC - State of the Art and Future Trends
Speaker: Jörg Dorn, Siemens, D

Wide Band Gap Devices I

Lateral GaN Transistors – High Density Layout Techniques
Geoff Haynes, John Roberts, Ahmad Mizan, GaN Systems, Ottawa, CA
GaN power transistors normally use a scaleable ladder or interdigitated finger structure in order to maximize channel width (Wg) and minimize the on-resistance (Ron). Since GaN devices can easily produce more than 1 amp per millimeter of channel width, the current density at the collection end of a 1mm finger could exceed 2x105 amps per cm2. Electromigration concerns begin at this level of current density. When the current collection is made external, in accordance with the alternative topolog

Increase Efficiency and Lower System Cost With 100kHz, 10kW Silicon Carbide (SiC) Interleaved Boost Circuit Design
Jimmy Liu, Kin Lap Wong, Paul Kierstead, Cree, USA
Nominated for the Best Paper Award
In this paper, design and performance of a 100kHz, 10KW interleaved DC/DC boost converter utilizing the novel 1200V silicon carbide (SiC) MOSFETs and Schottky diodes are presented. Ultra-low switching losses of SiC power semiconductors enables switching frequencies to be increased significantly over silicon implementations. Combined with an interleaved DC/DC topology, the effective operating frequency is up to ten times higher than achievable with conventional IGBT based 10KW boost circuits.

Breakthrough SiC GTO's Enable Efficient & Compact Next Generation High Voltage Grid Conversion
Anup Bhalla, Leonid Fursin, John Hostetler, Xueqing Li, Matthew Fox, United Silicon Carbide, USA; Frank Hoffmann, Princeton Power Systems, USA
Demand for smart, flexible photovoltaic power conversion is fueling rapid development of breakthrough 6.5 - 24 kV, wide-bang gap switches. Conventional si bipolar switches are limited to roughly 8 kV breakdown. Thick drift layers of si devices translate into very high minority carrier charge hence leading to extremely slow switching speeds and poor efficiency. USCi presents the development of 6.5 kV 4H-SiC gate-turn-off thyristors and demonstrates their performance in an AC-link converter.

Half Bridge Inverter with 600V GaN Power Switches
Radoslava Mitova, Alain Dentella, Miao-Xin Wang, Schneider Electric, F; Rajesh Ghosh, Uday Mhaskar, Schneider Electric, IND; Damir Klikic, Schneider Electric, USA
Winner of the Young Engineer Award
The emerging GaN power devices promise to outperform the actual Silicon devices and to challenge the Silicon Carbide ones in 600 voltage range thanks to their faster switching speed. This article presents evaluation of new GaN transistor devices in half- bridge inverter. The operation principle of these devices in half-bridge configuration is be detailed. Multiple measurements carried out on a dedicated test bench will show the performances of the GaN devices.

Advanced Power Substrate Materials

Comparison of Silicon Nitride DBC and AMB Substrates for Different Applications in Power Electronics
Manfred Goetz, Nico Kuhn, Bernd Lehmeier, Andreas Meyer, Ulrich Völler, curamik electronics, D
With the growth of HEV/EV and renewable energy applications, designers struggle to find new ways to ensure reliability and high efficiency of electronic systems.
curamik has developed Si3N4 substrates based on DBC (direct bond copper) and AMB (active metal brazed) technology, which both utilize the excellent material properties of Si3N4 ceramic like bending strength, high fracture toughness and good thermal conductivity as a metalized substrate.

Partial Discharge and Dielectric Breakdown Behavior of NiAu-Coated Substrates for Power Semiconductor Modules
Harald Beyer, Samuel Hartmann, Hamit Duran, ABB Switzerland, CH
Experiments on partial discharge and dielectric breakdown behavior of NiAu-coated copper-plated ceramic substrates with different designs are presented. Both properties are influenced by surface metallization, surface roughness, and ceramic material, but also by geometrical dimensions. The results are compared with electrical field simulations on corresponding substrate designs. Further investigations will be done with additional polyimide coating of bare ceramic surfaces.

Comparison of the Thermal Cycling Capability between Power Modules with DAB and DCB Substrates with Al_2O_3 Ceramic
Tilo Poller, Marco Bohlländer, Josef Lutz, Chemnitz University of Technology, D; Bianca Boettge, Fraunhofer IWM, D; Folkhart Grieger, Andreas Lindemann, Otto-von-Guericke-University, D; Heiko Knoll, IXYS Semiconductor, D
In the last years the interconnections between the dies and the substrate have been improved. Now the substrate becomes the main weak point which makes an improvement necessary. One option is a replacement of the copper layer with an aluminum layer (DAB substrates). DAB substrates were available with Al203 and AlN ceramics. In this paper the results of reliability tests are discussed which compare the capability of DCB and DAB with Al2O3 ceramics

Improved Thermal Cycling Reliability of Direct Copper Bonded Substrates by Manipulating Metallization Properties
Alexander Roth, KCC Europe, D; JunHee Park, Kyoung-Hun Kang, Eunbok Lee, In-Sig Seog, KCC Corporation, ROK
DBC aluminium-nitride substrates are important packaging components in automotive multichip power modules. By manipulating copper properties, it is possible to improve thermal cycling performance in conventional AlN-DBC substrates by at least a factor of two without a major change in the bill of material.

Motors and Actuators

Design of High-Speed Motors with a High Power Range for use in Future Aircrafts
Michael Doerbaum, Cornelia Stübig, Peter Juris, Bernd Ponick, University of Hannover, D
Nominated for the Young Engineer Award
In order to provide aircrafts with an active air flow control system, high-speed, electrical driven compressor systems are developed in a cooperation of electrical and mechanical engineers as a part of the Collaborative Research Center 880. This paper deals with the design of suitable high-speed motors and the challenges recaused by the boundary conditions, mainly space and weight restrictions as well as speeds ranging from 50,000 to 85,000 rpm at a power range of 130 to 170 kW.

Sensorless Direct Torque Control of Transverse Flux Machines with Hybrid Flux Conduction
Amir Ebrahimi, Florian Dreher, Nejila Parspour, University of Stuttgart, D
PM Transverse Flux Machines (PMTFMs) can achieve higher torque densities than conventional PM Longitudinal Flux Machines (PMLFMs).Unfortunately, controlling PMTFMs is usually quite complex. This is a key reason why this type of machine is hardly used for practical applications till now. This paper describes design rules which finally allow hybrid flux conduction inside the machine. In order to prove the advantage of the presented method, a complete prototype of the resulting machine design was put into operation with a Sensorless Direct Torque Control (DTC). The drive's control behavior during dynamic operation and field weakening was assessed and documented.

Balancing Torque Loss and Cogging Reduction at PM Transverse Flux Machines with Segmented Stator Phases
Florian Dreher, Amir Ebrahimi, Nejila Parspour, University of Stuttgart, D
PM Transverse Flux Machines (PMTFMs) can achieve higher torque densities than conventional PM Longitudinal Flux Machines (PMLFMs). Unfortunately, a general problem of PMTFMs is their high cogging torque compared to the average torque. One way to solve this problem is skewing at segmented stator phases. But this method reduces the average torque of the machine. The paper deals with this dependence and introduces a suitable compromise related to this problem.

Control Methods with Exactly Linearization for Magnetic Bearing with Multiple Inputs as Example for Grind Ball
Alexander Norbach, University of Bremen, D
The aim of this paper is to show how bring a magnetic system of a grind ball with grinding tool to the steady state. The magnetic bearing without touch has the advantage that the grinding tool has a contact only with work piece and fluid drive to supply cooling lubricant the surface of the work piece. The aim of IALB is to develop to the magnetic bearing for this problem. Further a regulation should be realised which allows it the grind ball to position magnetically in a stable point and unknown

Special Session “Solar Power I”

Optimization and Comparative Evaluation of Two-Level and Three-Level Voltage-Source Topologies for Three-Phase Photovoltaic Inverters
Julia Pinne, Artjom Gruber, Klaus Rigbers, SMA Solar Technology, D
Three-phase photovoltaic inverters are widely spread for medium power applications in these days due to good cost-benefit ratios and unbalanced load issues. In this paper, optimized designs for the two-level six-pulse (B6) and the three-level Bipolar Switched Neutral Point Clamped (BSNPC) topology are determined and evaluated with respect to measurements. The optimization is performed with the help of a computer-based integrated design and optimization approach for power electronic converters.

SiC-based High Efficiency Bidirectional Battery Converter for Smart PV Residential Systems
Cam Pham, Valeriu-Ciprian Biris, Remus Teodorescu, Tamas Kerekes, Laszlo Mathe, Aalborg University, DK
To maximize internal consumption of Smart PV inverter, a high efficiency bidirectional DC-DC converter for the battery storage is necessary as energy will be processed twice. Realisation of the battery converter with silicon carbide (SiC) semiconductors offers many advantages compared to Silicon (Si). In this paper a Si MOSFET based converter with SiC diodes will be compared against a converter based on SiC JFET and SiC diodes for the same application.

A New Topology for Solar Central Inverters with 99.2 % Efficiency
Heiko Preckwinkel, Lti Drives, D; Krishna DVMM, Norbert Fröhleke, Joachim Böcker, University of Paderborn, D
A new topology for central solar inverters connected to medium voltage grid is presented. The topology reaches a peak efficiency of 99.2 % and an European efficiency of 99.1 %. The work includes theoretical analysis of losses, modulation and working principles as well as practical examination on a 100 kW prototype.

High Efficiency Photovoltaic Power Conditioning System
Hosam Sharabash, Krishna DVMM, Norbert Fröhleke, Joachim Böcker, University of Paderborn, D
A new topology for photovoltaic PCS with high efficiency under wide input voltage range of the photovoltaic array is introduced. It consists of two new components, one for DC/DC converter and one for DC/AC inverter. The presented topology of DC/DC converter enhances the efficiency by partial power sharing, producing a multi-output voltage convenient to DC/AC inverter topology which enhances the efficiency too by reducing the conduction and switching losses of power electronic elements.

Thermal Management - Heat Sink

Investigation of an Aluminium-copper Clad Metal Baseplate for Liquid Cooling: Experimental Characterization and Thermal Modeling
Matt Reeves, Jesus Moreno, Peter Beucher, Sy-Jenq Loong and David Bono, Wolverine Tube, USA
A numerical and experimental study has been conducted in order to characterize a pin fin aluminum-copper clad metal baseplate. Analysis of results show that the pin fin aluminum-copper baseplate ex-hibits enhanced thermal performances compared to a full aluminum configuration and also significant weight and cost reduction when compared to an all copper configuration.

Aluminum Heat Sink Having an Integrated Copper Heat Spreading Structure for IGBT Attachment
Ralph Remsburg, Amulaire Thermal Technology, USA
A substantially pure Aluminum heat sink fin structure is bonded to a pure Copper heat spreading structure. When compared to a copper heat sink of equal pressure drop the composite heat sink is 50% of the weight, has 40% of the material cost, and 96% of the thermal performance. Several factors combine to make this heat sink unique. The work hardened fin structure is 1000 series aluminum (99.50% aluminum) while the copper heat spreader is manufactured from 10100 series copper (99.99% copper).

Two-phase roll-bond heat sink for power electronics cooling
Francesco Agostini, Thomas Gradinger, ABB Switzerland, CH
In this paper a novel heat sink thermosyphon design based on roll-bond technology for power electronics cooling is presented and supported by an extensive experimental campaign. The work tackles the problem of finding a suitable substitute of common air cooled heat sinks towards a highly thermally performing device overcoming the bottleneck of limited fin efficiency and proposing a device with reduced air pressure drop. Power losses range from 1 to 3.5 kW; refrigerant fluid R245fa.

Geometry, Shape and Accelerated Aging Impact on Heat Sinks Made out of Metal-diamond Composite
Michael Kitzmantel, Erich Neubauer, RHP-Technology, A
High performance heatsinks containing diamond particles often face the challenge lacking complex shapes or appropriate surface qualities. This work addresses the technology of manufacturing individually shaped parts when using metal-diamond materials as well as its influence on the thermal performance of the material due to machining or thermal treatment. Accelerated aging procedures or high temperature brazing processes can have severe impact on the composite material itself.

Power Module Design I

Implementation of Low Inductive Strip Line Concept for Symmetric Switching in a New High Power Module
Georg Borghoff, Infineon Technologies, D
The low inductive strip line concept offers many chances for better switching behavior of IGBT modules. For the implementation in real packages a lot of boundary conditions have to be considered, such as standards, available material, manufacturing methods and the connectivity to the rest of an inverter system. In this work it will be shown how an implementation could look like for high power modules. Variants will be shown and compared.

Fast Switching Behavior of IGBTs with High Inductance and Capacitive Load
Christian Müller, Nils Kerstin, Infineon Technologies, D; Benno Weis, Hubert Schierling, Siemens, D
Fast switching behavior of IGBTs is investigated up to four times the nominal current with an inductive load connected via a 200m motor cable. In a power-integrated module, fast IGBTs with a reduced short circuit withstand capability were integrated as switches. The experimental waveforms show expected reflection on VCE and IC. It is shown that even for these large parasitics very quick short-circuit detection, which is required for fast switching IGBTs, is still possible.

Ultra-Low-Inductance Power Module for Fast Switching Semiconductors
Eckart Hoene, Andreas Ostmann, Binh The Lai, Christoph Marczok, Fraunhofer IZM, D; Andreas Müsing, Johann Walter Kolar, ETH Zürich, CH
Winner of the Best Paper Award

Passive Components and New Materials

Increasing the Life of Electrolytic Capacitor Banks Using Integrated High Performance Film Capacitors
Edward Sawyer, Michael Brubaker, Dayana El Hage, Terry Hosking, H. Kirbie, SBE, USA
A hybrid film/electrolytic bank is presented for alternative energy DC link capacitor applications. An advanced film capacitor supplies the high frequency ripple current harmonics and the electrolytic capacitors provide energy for ride-through of grid events. This approach reduces the electrolytic losses and offers the ability to substantially increase service life. Simulation results and test data are presented to illustrate the concept.

Glasses and Glass Ceramics as Dielectrics for High Power Capacitors
Martin Letz, Schott, D
Ultra thin glass foils made from industrial glass production have a dielectric breakdown strength which strongly increases with decreasing thickness, a value of 590 kV/mm has been measured on 0.025 mm thick glass. This offers the possibility to make high temperature stable capacitors with excellent storage capacity. A second class of materials which can be applied for capacitors are pore free glass ceramics with para- or ferroelectric nano-crystalline phases obtained via a true glassy phase.

Design of a Transformer with Integrated Current Doubler for an Automotive On-Board Power Supply
Thiemo Kleeb, Daniel Gottschalk, Florian Fenske, Peter Zacharias, University of Kassel, D
A known method for achieving high efficiency, small volume/weight, low cost and a high power density is the functional integration of magnetic components. A transformer with an integrated current doubler for an automotive on-board power supply will be presented. The focus of the investigation is the design of the transformer where not only the loss calculation but also the parasitic leakage inductances of the device where taken into account for the design procedure.

Design of thermally integrated planar inductors utilising aluminium oxide as a winding insulation material
David Hewitt, David Stone, Martin Foster, University of Sheffield, UK
An investigation of planar inductors employing aluminium oxide winding insulation. This forms an electrical insulation with superior thermal performance over conventional winding insulations, resulting in a more uniform temperature distribution within the inductor windings. In this work the electrical properties of aluminium oxide are verified; methods of joining the aluminium windings together are evaluated; and finally a test inductor is produced, the performance of which is verified.

Control Techniques in Intelligent Motion Systems

Simple Strategy of Overmodulation in Control of Interior Permanent Magnet Synchronous Machines for Improving Efficiency in Automotive Applications
Tobias Gemaßmer, Mathias Schnarrenberger, Helmut Späth, Michael Braun, KIT Karlsruhe Institute of Technology, D
Nominated for the Young Engineer Award
A new strategy of voltage limitation for the current control of interior permanent magnet synchronouos machines with increased inverter output voltage through the use of overmodulation is being presented. The proposed limitation scheme allows the use of dynamic rotororiented current control with no modifications for operation in overmodulation range. The novel limitation structure is described and verified through simulations and experimental results.

Freely Programmable Model Based Control in Combination with High Bandwidth Current Control for Applications with Medium Switching Frequencies
Jens Krah, Heiko Schmirgel, Leif Fischer, Cologne University of Applied Science, D
One way to achieve high bandwidth current control is the use of high switching frequencies. Drawbacks are higher switching losses which decrease the drive efficiency and increases heat sink size and cost. This contribution describes how model based control can be used in a very resourceful way by utilizing a Luenberger Observer in conjunction with current prediction to enable high bandwidth current control at lower and therefore more energy efficient switching frequencies.

General-Purpose Full-Speed-Range Sensorless SPM Drive: Low-Frequency Injection and Robustness Improvement
Sandro Calligaro, Roberto Petrella, University of Udine, I
For the sensorless control of non-salient PMSMs at low-speed and stand-still, an integrated approach comprising low-frequency current injection for position-speed estimation and a more general reactive current-based speed control stabilization technique is proposed in this paper. Analytical description of an initial position detection and a closed-loop control technique are provided, together with simulation and experimental investigation on a general-purpose industrial drive.

Energy Storage Systems

Application of Maximum Length Sequences to Battery Charge Programming for Parameter Estimation in Lead-Acid Batteries
Andrew Fairweather, David Stone, Martin Foster, University of Sheffield, UK
This paper continues previous work using maximum length sequences in parameter estimation for batteries Implementation of designed charge current waveforms using Pseudo Random Binary Sequences as an excitation signal for battery state evaluation is explored. The work is supported with experimental investigations, and the correlations obtained are subsequently presented as the basis for a parameter estimation system which can be used on-line during battery charging.

Understanding the Unbalancing of a Battery Pack to Choose the Best Balancing Solution
Laurent Garnier, Daniel Chatroux, CEA, F
In a Lithium Ion battery pack, it is necessary to balance the pack in order to guarantee that at the end of the charge, all cells are fully charged. This step is necessary, otherwise the available energy stored will decrease continuously charge after charge.
Understanding why we need a balancing system and how it has to sized is an important question for the designer. This paper try to answer to this question.

Performances of Batteries Technologies in Vehicle Applications
Daniel Chatroux, CEA, F
The main four batteries technologies for electric vehicles are lead acid, NiCd, NimH and Lithium batteries. Mainly, these technologies are compared with the supplier specifications. In our laboratory, monitoring of electric vehicle prove important differences between the supplier specifications and real use performances because of the specification conditions. The goal of this presentation is to focus on the main parameters to select battery technologies for electric vehicle application.

Power Quality Solutions

Power Infrastructure for High-Efficiency IT Installations
Lorenzo Giuntini, General Electric Consumer & Industrial, CH; Enrico Blondel, Swisscom, CH
The IT infrastructure is crucial for most organizations, and it is often hosted in a data center facility, providing controlled conditions for reliable and continuous operation. In these energy-greedy applications, power and cooling accounts for a relevant portion of the overall consumption. This paper discusses “green” technologies for power and cooling in IT applications, focusing on high-efficiency UPS protection, presenting field results from a pilot installation.

Novel Active Damping Scheme for LCL Filters of Grid Converters with Optimal Pole Placement by Proportional Capacitor Current Feedback
Martin Wagner, Tobias Barth, Rodrigo Alvarez, Steffen Bernet, Technical University of Dresden, D
For the active damping of LCL resonance in grid connected converters the proportional feedback of the capacitor current is analyzed in the discrete time domain and an analytical solution for an optimal damping scheme is derived. Little computational effort is needed in order to implement the novel active damping scheme. The performance of the new algorithm is shown through analysis in the z-domain and experimental investigation.

Novel Inductive Current Splitter/Merger for Low Harmonics Three-Phase Rectifiers
Andrzej Pietkiewicz, Schaffner Group, CH; Kurt Schenk, Tobias Gnos, Martin Bünner, Interstate UAS of Technology Buchs, CH
Nominated for the Best Paper Award
We present a design oriented analysis of the inductive Current Splitter/Merger, CSM, which is intended for low harmonics three-phase power rectifiers. The goal is to derive a reluctance model, representing both electrical and magnetic quantities of the inductive CSM. The model is needed for the analysis and design optimization process. It enables the use of standard circuit simulation tools for both, the electrical design of the whole rectifier and the magnetic design of the CSM component.

Poster/Dialogue Session

Power Devices I

New Approaches for Highly Dynamic Current Measurements of Extremely Fast Switching IGBTs
Stefan Hain, Mark-M. Bakran, University of Bayreuth, D
Nominated for the Young Engineer Award
In this paper, different approaches are presented, which allow to measure the current flow of extremely fast switching IGBTs with low additional inductance and high bandwidth by using the unavoidable parasitic inductance of the existing circuit as an inductive sensor. Furthermore, a concept for a new generation of Rogowski-Coils is presented which are resistant to capacitive coupling without reducing the bandwidth.

Elimination of Signal Time Delays for Precise IGBT Switching Loss Measurement
Ole Binder, Michael Kurrat, Technical University of Braunschweig, D; Johann Meisner, Physikalisch-Technische Bundesanstalt, D
Insulated gate bipolar transistors are capable of fast switching between on- and off-state. For switching process, a time delay between measured current and voltage signals can lead to a significant miscalculated power loss value. Solutions for time delay compensation for the measurement system components are presented.

Four Quadrant Converter on AC Welding Application
Francisco Javier Azcondo, Alejandro Navarro-Crespin, Victor Manuel Lopez-Martin, Rosario Casaneuva, University of Cantabria, ES
AC current is required to weld metals such as aluminium and magnesium. A four quadrant synchronous rectifier (4QSR) is used to convert HF AC (125 kHz) into LF AC current. The resonant converter operates in current source mode; therefore the elimination of the dead time of the converter drive signals reduces switching losses and noise while operation is safe under an eventual short circuit condition. Switching times are accurately controlled by a predictive algorithm implemented in an FPGA providing 20 ns time step resolution, i.e. 0.9º, to synchronize the converter drive signals with the output current phase.

Potential of RC-IGBT in the Rotor Side Converter of DFIG for Wind Energy Application
David Weiss, Daniel Wigger, Hans-Günter Eckel, University of Rostock, D
Bi-Mode Insulated Gate Transistors are a new class of power semiconductors, which integrate the functionality of IGBT and free-wheeling diode in one chip. Due to this fact the output current in comparison to an IGBT / diode module can be increased. Furthermore the power cycling stress of the module is decreased. In this paper the
potential of the BIGT in the rotor side converter of a doubly fed induction machine for wind energy application will be shown.

Impact of Inhomogeneous Current Distribution on the Turn-off Behavior of BIGTs
Daniel Wigger, David Weiß, Hans-Günter Eckel, University of Rostock, D
Winner of the Young Engineer Award
The BIGT shows a soft turn-off behavior in the IGBT-mode. A reason for the soft behavior is the dynamic avalanche, which limits the dvCE/dt and the electric field in the device. In com-parison to IGBT with the same current density, the dynamic avalanche inception voltage of BIGT is significantly lower. This is caused by an inhomogenous current distribution inside the BIGT, which leads to a higher hole density in regions with higher current and thereby to a higher gradient of the electrical field. In this paper the influence of the current distribution on the turn-off behavior will be described.

A Novel Structure of Planar-Gate IGBT with Topside Diffusion Remnant Layer
Bin Zhang, Yan Han, Shifeng Zhang, Dazhong Zhu, Zhejiang University, CN
According to the existing domestic technology of power device, a novel structure of high-voltage planar-gate IGBT and its manufacturing are introduced in this paper. Based on the high temperature ultra-deep diffusion process, the topside remnant layer is used to weaken the JFET resistance. Not only can reduce the JFET implant process, saving production costs, but surface doping profile of the remnant layer, which was retained after grinding the diffusion layer formed by high temperature ultra-deep diffusion, obtains the linearly graded junctions characteristics. Thus, compared with conventional JFET implant method, the forward blocking voltage of novel IGBT decreases more slowly with the decline of on-state voltage while the current capacity of device increases significantly.

Effect of Parasitic Parameters on Switching Characteristics and SOA of the TRENCHSTOP™ 5 IGBT
Fabio Brucchi, Infineon Technologies Austria, A
Newly introduced Infineon TRENCHSTOP™ 5 technology enables final customers to achieve extremely high hard switching commutation frequencies than the previous Trench FieldStop IGBT technologies. Aim of the present paper is to explain how to fully exploit the switching capabilities of this technology in real customer applications, without impacting on application performances and product reliability.Findings on the right matching between IGBT and FWD are reported.

A New 1200V High Speed Field Stop Trench IGBT
Sungmo Young, Wanki Hong, Fairchild Semiconductor, ROK
A new fast switching 1200V field stop trench IGBT is developed. This new IGBT combines both low Vce(sat) and small switching loss, and meets application specific needs of photovoltaic inverters, welding machines, or on-line UPS.

An Automated Test Set-up for the Dynamic Characterization of IGBT Modules under Different Thermal and Electrical Conditions
Ionel Hemp, Lutz Göhler, Sven Bönisch, University of Applied Science Lausitz, D
This work deals with the investigation of the transient behavior of an IGBT module under various thermal and electrical conditions. Both the transients of the IGBT and the freewheeling diode are investigated separately. It will be demonstrated, how powerful the influence of the gate driver design is. Additionally, an equivalent circuit has been build up in Portunus® to validate the macro model of the IGBT module.

Using 650V High Speed 3 IGBTs in Power Modules for Solar Inverter Performance Improvement
Christian Müller, Jens De Bock, Infineon Technologies, D
In this paper, the difference between the 650V IGBT3, 650V IGBT4 and the 650V High Speed Three (HS3) IGBT from Infineon Technologies used in power modules will be described. It will be shown that due to the device design, the 650V HS3 IGBT provides a superior performance and can be used as a high efficiency switch with focus on high frequency hard switching applications, e.g., solar inverters. The requirements to achieve this high efficiency by using the 650V HS3 IGBT will be explained as well.

An Evaluation of Novel Intelligent Power Modules for 500W Washing Machine Motor Drives
Myungbok Kim, Bong-Woo Kwak, KITECH, ROK; Junbae Lee, LS Power Semitech, ROK
The CIPOS™ modules were introduced for variable-speed motor drive application such as refrigerators, washing machine, and air conditioners as a most-optimized solution. In this paper, the evaluation works of the modules for 500W washing machine motor drive system are provided where the application requires wider speed operations with field weakening control.

Localization of Electrical Active Defects on Power Devices Using Lock - in Thermogrpahy and Thermal Trigger Delay
Christian Schmidt, DCG Systems, D; Toshi Nagatomo, DCG Systems, J; Koichi Endo, Toshiba Corp.,J
In this paper, the method of Lock-in Thermography is presented which is a enhanced Thermography method leading to high spatial resolution (~1µm) and high sensitivity (single µW). Thus the method enables thermal investigations for fault isolation (e.g. electrical shorts) on power devices. Presented on case studies, the operational principle as well as the advantages for non-destructive defect localization are shown. These case studies include the possibility of detecting electrical active defects buried under metal layer and in close distance to bond wires as well as the prediction of break-down positions. Furthermore the newly developed approach for defect depth estimation by quantitative phase shift analysis is explained which allows a fully 3D defect localization on future 3D power device structures.

Power Devices II

Irradiated HV Power MOSFETs Working in Linear Zone: a Comparison of Electro-thermal Behavior with Standard HV Products
Daniela Cavallaro, Giuseppe Consentino, STMicroelectronics, I
This paper studies the thermal instability phenomenon of irradiated HV power MOSFET devices working in Linear Zone operating conditions and compares their electro-thermal behaviour with standard products. Experimental results show that irradiated are more thermal instable than standard devices, thus, they should be used carefully in this particular operating conditions.

New Generation Super-Junction MOSFET for Lower Switching Noise and Reliable Operation by Controlled dv/dt and di/dt Switching Behavior
Markus Hallenberger, Fairchild Semiconductor, D; Wonsuk Choi, Dong-kook Son, Fairchild Semiconductor, ROK
Nominated for the Best Paper Award
Super-Junction MOSFET based on charge balanced technology offer outstanding performance with respect to reduced both on-resistance and parasitic capacitances, which usually are in trade-off. With smaller parasitic capacitances, the super-junction MOSFETs have extremely fast switching characteristics and therefore reduced switching losses. However, without dv/dt control, the drain-source voltage slew rate reach up to 100V/ns, which could lead to EMI problem and unstable operation related to the s

Super-Junction HV MOSFETs Boost Efficiency of SMPS and Lighting applications
Salvatore La Mantia, Antonino Gaito, Vittorio Giuffrida, Santina Leo, STMicroelectronics, I
The goal of this paper is to show that HV Super-Junction MOSFETs rated from 800V up to 950V BVDSS can enable higher energy efficiency than conventional planar Power MOSFETs in applications requiring high BVDSS devices with outstanding RDS(on) and switching dynamics per package type. Three different MOSFET technologies have been selected in the tests. The main technology features and benefits will be introduced.

Repetitive Avalanche of Automotive MOSFETs
Marco Pürschel, Dirk Ahlers, Mario Eicher, Infineon Technologies, D
This paper will focus on one of the most difficult operation modes of automotive MOSFETs, the avalanche mode. Whereas single pulse avalanche conditions are very well defined and tested, repetitive operation is always an area of questions.
Requirements from application point of view will be explained, some basic information on avalanche mode given, tests in avalanche either on single but as well in repetitive avalanche mode explained and the test results assessed.

Circuit-simulation Methodology for Application-specific Device Design for Mid-voltage MOSFETs
Tirthajyoti Sarkar, Fairchild Semiconductor, IND; Roman Gurevich, Scott Pearson, Joe Yedinak, Rick Stokes, Fairchild Semiconductor, USA; H.L. Lin, Alan Wang, Fairchild Semiconductor, TW
Among power devices, mid-voltage i.e. 40-200 V breakdown rated MOSFETs are used in diverse application segments. One key performance metric is the power conversion efficiency which depends on the loss in the MOSFETs. System-related considerations must be taken into account while designing a new generation of technology for MV MOSFETs to make it more suited to customers' specific needs. In this article, we focus on the description of such an integrated design effort through Pspice simulations.

Turn-on Behavior of Power LTT and Light Driver Modules
Alexey Khapugin, Valentin Martynenko, Aleksandr Plotnikov, JSC Elrctroviprymitel, RUS; Andrey Konyukhov, Moscow All-Russian Electrotechnical Institute, RUS; Gevork Mikaelyan, S.N. Sokolov, Inject JOSC RME, RUS
Turn-on characteristics of high voltage power Light Triggered Thyristors (LTTs) and information about new light control drivers for different applications.

High Voltage Thyristor with Reduced Temperature Dependence of Reverse Recovery Characteristics Adapted for Usage in Series Assembly
Alexander Pisarev, Alexey Surma, Anatoly Chernikov, JSC Proton-Electrotex, RUS
Development of high voltage thyristors, which have reduced temperature dependence of reverse recovery characteristics adapted for usage in high voltage converters with series connection by means of using technology with deep p-emitter, which has low injection rate

Recent Advancements in Thyristor Developments for HVDC Applications
Olarotimi (Timi) Akinbote, Ashley Plumpton, Michael Spence, Michael Qin, Dinesh Chamund, John Swingler, Dynex Semiconductor, UK
This paper looks at recent technology and design advances of large area high voltage thyristors aimed at industrial and HVDC transmission applications. It discusses the design and fabrication issues involved in development of a 12kV 88mm Series Connected ASCR/Diodes as well as in the realization of low temperature bonded 8.5KV, 125mm HVDC Thyristors.

Extension of operating temperature range of rectifier diodes
Boris Rosensaft, Paul Strobel, Arendt Wintrich, Semikron Elektronik, D
Presentation about a new rectifier diode with Tvjmax 175°C

Wide Bandgap Power Devices

GaAs Pin Diodes as Possible Freewheeling Diodes
Jens Kowalsky, Thomas Basler, Riteshkumar Bhojani, Josef Lutz, Chemnitz University of Technology, D; Volker Dudek, Clifton, D; Dmitri Opalnikov, Viktor Voitovich, Clifton, EST
GaAs is a direct semiconductor with a bandgap of 1.42eV. The direct bandgap has the consequence of a low lifetime. Additional, GaAs has high electron mobility, so for a bipolar device low switching losses combined with low conduction losses can be expected. In this contribution the potential of GaAs pin-diodes shall be investigated.

1200V SiC MOSFET and N-off SiC JFET performances and driving in high power-high frequency power converter
Luigi Abbatelli, Bettina Rubino, Giuseppe Catalisano, Simone Buonomo, STMicorelectronics, I
The present work proposes a comparative analysis between a 1.2 KV SiC MOSFET and a 1.2 KV N-off SiC JFET on a real 6KW demonstrator at different power levels and different fsw values. Beyond the evaluation of their electrical and thermal performances, a special focus is dedicated to the driving aspect. It will be shown that the SiC MOSFET achieved higher efficiency than the JFET in all power levels at 25 KHz,requiring at the same time the simplest driving approach.

Switching optimization of WBG power devices on inverter leg
Timothé Rossignol, Fiacre Senghor, Damien Risaletto, Jean-Marc Blaquière, Frédéric Richardeau, Marc Cousineau, G. Aulagnier, LAPLACE - University of Toulouse, F
SiC and GaN are known for extremely fast and low losses switches, as a result very high dv/dt commutations that are clearly sources of very hard perturbations. In this article the authors present results of many characterization campaigns synthesized in trade-off curves between dv/dt and switching energy. Measurement campaigns characterize SiC WBG competitors components. The external gate resistor and the feedback capacitance are the variable parameters.

Opposition Method Based Test Bench for Characterization of SiC Dual MOSFET Modules
Joseph Fabre, Michel Piton, ALSTOM Transport, F; Philippe Ladoux, LAPLACE - University of Toulouse, F
Silicon Carbide technology is pushing the limits of switching devices in three directions: higher blocking voltage, higher operating temperature and higher switching speed. The authors propose to use the opposition method to compare Si IGBT and SiC MOSFET modules in a voltage source inverter (VSI) operation. To this effect, a test bench, allowing electrical and thermal measurements, was developed.

High Switching Speeds and Loss Reduction: Prospects with Si, SiC and GaN and Limitations at Device, Packing and Application Level
Samuel Araujo, Thiemo Kleeb, Peter Zacharias, University of Kassel, D
Winner of the Young Engineer Award
The prospect of increasing the switching frequency without sacrificing efficiency is seen in many fields of application as a promising development. This will be mainly achieved through new device technologies, not only relying on WBG materials but also on silicon, capable of operating at much faster switching speeds and thus with lower losses. On the other hand, new developments in the field of packing and montage are necessary in order to fully exploit new device capabilities.

True-Bridgeless Totem-Pole PFC Based on GaN HEMTs
Umesh Mishra, Liang Zhou, YiFeng Wu, Transphorm, USA
This paper presents a true bridgeless totem-pole Power-Factor-Correction (PFC) circuit using GaN HEMT. Enabled by 3-qualdrant GaN power HEMT with low reverse-recovery charge, very-high-efficiency single-phase AC-DC conversion is realized using a totem-pole bridgeless PFC topology. When implemented with a pair of sync-rec MOSFETs for line rectification,98.97% efficiency is achieved at 230V ac input and 400 dc output in continuous-current mode.

High Voltage, High Frequency Lateral SiC JFET for Next Generation DC-DC Power Supply
Peter Alexandrov, Xueqing Li, John Hostetler, United Silicon Carbide, USA
Nominated for the Best Paper Award
USCi presents a novel 1kV, 5A SiC SL-JFET device as part of a dc-dc converter capable of operating at >2MHz resonant switching frequency with >97% efficiency, targeted for mid power dc-dc converters. The high frequency capability is a unique feature of the SiC L-JFET that greatly reduces the size and weight of the converters. Another fundamental advantage of SiC is its 3X higher thermal conductivity. The high efficiency of SiC switching at MHz coupled with its superior thermal characteristics ma

A 45W LLC Resonant Converter in MHz Frequency Region for Laptop Adapter Application using GaN HEMTs
Hari Babu Kotte, Radhika Ambatipudi, Kent Bertilsson, Mid Sweden University, S
The authors report the feasibility of low profile, high power density and energy efficient isolated DC/DC converter in 3 – 4 MHz frequency region for low line input voltage of 90 – 110 Vac suitable for 45W laptop adapter application. Using novel power transformer, GaN MOSFETs, the simulation and experimental results of LLC resonant converter without bridge rectifier for corresponding low line input voltage with a regulated output voltage of 22Vdc and maximum efficiency of 90% was presented

Packaging and Thermal Mangement

Energy-efficient Cooling Using Microstructures for Nucleate Boiling Process
Mike Zinecker, Andreas Schubert, Matthias Hackert-Oschätzchen, Chemnitz University of Technology, D; Martin Lausberg, cool tec Electronic, D
In power and high-power electronic components high amounts of power loss in form of heat occur. For a specific dissipation of the heat conventional cooling technologies such as air or water cooling are often not sufficient. In this study an innovative cooling technology is demonstrated in which the heat is removed by intense boiling of a working fluid. In this special technology microstructures on the inner walls of the evaporation module lead to a significant increase in boiling rates.

Electro-thermal Model of Power Semiconductors Dedicated for both Case and Junction Temperature Estimation
Ke Ma, Frede Blaabjerg, Marco Liserre, Aalborg University, DK
In order to overcome the shortage of Foster and its equivalent Cauer thermal models, a new thermal model is proposed and verified by simulation in this paper. It is concluded that by the proposed thermal model, it is possible to extend the Foster thermal network inside power semiconductor device, achieving relative more accurate estimation of both junction and case temperature.

Mixed PRBS Technique for Thermal Impedance Spectroscopy of Power Electronic Systems
Jonathan Davidson, David Stone, Martin Foster, University of Sheffield, UK
A technique to increase the usable frequency range of a pseudo-random binary sequence (PRBS) by mixing multiple sequences for thermal impedance measurement is presented. This allows the complex thermal impedance to be determined in less time and with greater noise immunity compared to unmixed PRBS techniques. Practical results have shown good agreement with, and reduced noise over, equivalent unmixed PRBS techniques.

Thermal Optimized Operation of the Single-Phase Full-Bridge PV Inverter under Low Voltage Ride Through Mode
Huai Wang, Yongheng Yang, Frede Blaabjerg, Aalborg University, DK
Achieving more reliable PV inverters is of intense interest in recent research, while the penetration of PV systems is booming continuously. As one of the most critical stresses that induce failures, the thermal stresses of a single-phase full-bridge PV inverter are analyzed in different operation modes.The solar irradiance profiles and the faulty grid conditions are also taken into account. The analysis is demonstrated by a 3 kW single-phase full-bridge PV system.

The Junction Temperature Estimation Model for Inverter Power Module
HanGeun Jang, JeHwan Lee, SangChul Shin, JungHong Joo, JinHwan Jung, Hyundai Motor, ROK
The thermal characterization of power module is important feature for the performance and reliability of hybrid electric vehicle (HEV) inverter. Power loss is calculated through the experiment of switching characteristics with direct cooling heat sink (pin fin structure) and the thermal impedance is obtained by testing with cooling characteristics. Data from these experiments are used as an algorithm to estimate the junction temperature accurately with various HEV driving conditions.

Simulation vs. Measurement of Transient Thermal Resistance Zth of Power Modules and its Effect on Lifetime Prediction
Andreas Groove, Markus Thoben, Krzystof Mainka, Ronny Herms, Infineon Technologies, D
The Zth of a power module describes a key performance. Here Simulation and VCE(T)-measurement based Zth are compared. Only simulation based Zth agrees well with the temperatue in short circuit tests . Delays between switch off of load current and start of measurement in large power modules have a significant impact on the short-time thermal resistance. The influence of the deviation in Zth on the lifetime prediction has been discussed.

Superior Thermal Stability by Enhanced Base Plate Design Combined with Dedicated Thermal Interface Material
Martin Schulz, Marc Essert, Wilhelm Rusche, Infineon Technologies, D
The paper describes the development of a new module base plate and the possible adaptations to reduce the pump-out influence to thermal grease. Measurements of different base plate types in combination with various thermal interface materials are presented.

A new Aluminium Alloy for Heavy Wire Bonding in Power Electronics – First Tests of Bonding Behavior and Reliability
Ute Geißler, Klaus-Dieter Lange, Technical University of Berlin, D; Jens Göhre, Martin Schneider-Ramelow, Fraunhofer IZM, D; Sven Thomas, Heraeus Materials Technology, D
Aluminum wire bonding is mainly used in COB (Chip on Board) technology with fine wires (AlSi1, d≤ 25 µm) and in power electronics with heavy wires (pure Al 4N/5N, d ≥ 100 µm) [1].
In both cases the wire material is required to support a stable bonding process and a high reliability of the bonds in the heel area and the bond interface. Currently there is a growing demand for wires which are also suited for high temperature applications. Typical pure Al or AlSi1 wires are usually not well suited

Fabrication of a Double-side Cooled, High Temperature Power Module with Sintered Nanosilver Interconnect for Automotive Applications
David Berry, Li Jiang, Khai Ngo, G.Q. Lu, Virginia Polytechnic Institute and State University, USA; Guangyin Lei, Ford Motor Company, USA; Susan Luo, NBE Technologies, USA
One way to reduce the cost of future electric vehicles is by developing reliable high-temperature power inverter modules that can be cooled directly from the radiator coolant. This demands packaging technologies that can enable silicon power semiconductor devices to reliably work at higher junction temperatures. We focus on a thin planar structure that utilizes the emerging low-temperature joining technology (LTJT) to maximize surface area for cooling from both sides of a package.

MAXIKON Copper Ribbon Bonding for Power Electronics
Wolfgang Reinert, Magdalena Kontek, Fraunhofer ISIT, D
The poster will present results of the german MAXIKON project. A heavy copper ribbon bonding process has been achieved on Ag pressure sintered test diodes with thick copper metallization. The poster will be updated for the power cycling results obtained with functional sample B that will feature staggered loops.

Solving the Power Module Challenge for 6 MVA+ Low Voltage Converters
Reinhard Helldoerfer, Ralf Ehler, SEMIKRON Elektronik, D
Solving the power module challenge for 6 MVA+ low voltage converters
A new approach for a modular SKIN based very high power product family

Multilevel and HVDC

Study of Parallel Single Transistor ZVS Resonant Inverter with Direct Settle of Steady Mode
George Kraev, Nikolai Hinov, Nikola Gradinarov, Dimiter Arnaudov, Technical University of Sofia, BG
The present paper is going into work of single transistor inverter without starting transient processes. Thus the inverter starts working directly in steady mode. Main advantage of the converter is the avoidance of switching on procedure, which makes easy its control, adjustment, protection and operation. Another advantage of the power circuit is its soft voltage commutation – zero voltage switching (ZVS).

Implementation Issues Designing a Multilevel Converter Control for FPGA-based Hardware in Simulink
Patrick Schmid, Reinhard Schneider, Vorarlberg University of Applied Sciences, A
FPGA hardware is a flexible and powerful solution for converter control. In this paper it is shown that it is possible to implement a multilevel back to back converter on a FPGA using Simulink with minimal hardware involvement and without vendor-specific design tools and libraries. The generator sided control using a 3-level rectifier and the used SVPWM is treated in detail. Implementation hints are given to avoid problems during the process of making the system HDL-synthesizable.

Hybrid Modulation and Optimal Neutral-Point Voltage Control for Three-Level NPC Inverters
Alessandro Pevere, Sandro Calligaro, Roberto Petrella, University of Udine, I
In this paper, a hybrid modulator with an appropriate NP-controller for a three-level NPC inverter under different power factor (PF) and modulation index conditions is investigated. This approach allows to reduce switching losses, at the cost of some low-frequency voltage oscillations at the NP, whose control performance is raised by an optimal controller.

Active Gate Control Methods for the Turn-On of High-Voltage Power MOSFETs in Hard Switching Applications
Stephan Brueske, Friedrich W. Fuchs, Christian-Albrechts-University of Kiel, D
In this paper an analysis of turn-on active gate control for high-voltage power MOSFETs to reduce the reverse-recovery current of the body diode is presented. Two gate drive circuits are analyzed in theory and simulation which have been applied for IGBTs already. The gate drive circuits are investigated and compared with the common basic gate drive circuit.

Analysis of a New Third Harmonic Injection Active Rectifier Topology Based on an NPC Three Level Converter Cell
Markus Makoschitz, Hans Ertl, Technical University of Vienna, A; Michael Hartmann, Rudolf Fehringer, Schneider Electric Power Drives, A
The paper analyzes a new topology for unidirectional active three-phase rectifiers. The proposed concept is realized as an extension/option to standard passive diode rectifiers with DC side smoothing inductor. A third-harmonic current injection based on three low-frequency switched bidirectional switches on the AC side is used. Two DC-side current sources realized as 3-level NPC topology which modulate the diode rectifier output currents such that finally sinusoidal mains input currents appear.

A Five-Level High Frequency Zero-Voltage-Switching Neutral-Point-Clamped Inverter for Energy Transfer with Resonant Tank
Christian Düerkop, Klaus F. Hoffmann, Helmut Schmidt University of Hamburg, D; Oliver Woywode, Philips Medical Systems DMC, D
This paper presents a new energy transfer system without both a buck-converter and an h-bridge inverter. The proposed system consists of a five-level inverter which bases on the multi-level topology of the Neutral-Point-Clamped inverter. This five-level inverter can generate the same output power as the system with the h-bridge by using a wide DC-link voltage range.

Benefits of Operating Doubly Fed Induction Generators by Modular Multilevel Matrix Converters
Felix Kammerer, Mario Gommeringer, Johannes Kolb, Michael Braun, Karlsruhe Institute of Technology, D
The benefits of supplying the rotor circuit of a Doubly Fed Induction Generator (DFIG) by the Modular Multilevel Matrix Converter (M3C) are presented. The M3C allows higher rotor voltages, lower rotor currents and a higher redundancy compared to existing solutions. Filters are dispensable due to the generated multilevel voltages. In case of a line voltage drop the M3C arm voltages can be used to generate temporarily higher rotor voltages which may help to control the rotor currents during faults

Boosting the Efficiency of Low Voltage Modular Multilevel Converters beyond 99%
Johannes Kolb, Felix Kammerer, Philip Grabherr, Mario Gommeringer, Michael Braun, Karlsruhe Institute of Technology, D
Nominated for the Young Engineer Award
The Modular Multilevel Converter (MMC) is an upcoming topology for high efficiency power conversion not only in the high voltage range. Several improvements in the hardware design, control and modulation of a low voltage MMC to increase the efficiency over 99% are presented. Simply standard Silicon-MOSFETs are used as semiconductor switches in the prototype. The analysis of the efficiency also shows an excellent performance in the low power range, which yields to a very flat efficiency curve.

A Sub-Module for Modular Multilevel Converter of HVDC
Sun Jian, He Hongtao, Song Gaosheng, Mitsubishi, CN
Voltage source converter based on high voltage direct current (VSC-HVDC) has been widely used in the transmission areas,and modular multilevel converter (MMC) is a new voltage source converter topology for HVDC. MMC consists of three phases and each phase has the same number of sub-modules (SMs) in series in upper and lower leg. This paper shows the topology and operating principle of MMC and how to build a sub-module by using HV-IGBT.

Transformer-less MMC-based HVDC systems for offshore locations
Carsten Heising, Roman Bartelt, Avasition, D; Volker Staudt, Andreas Steimel, Ruhr-University of Bochum, D; Thomas Jan Lebioda, Andreas Menze, Christian Rathke, TenneT Offshore, D
State-of-the-art HVDC systems are realized with a transformer-input stage. In offshore applications, the non-separable enormous weight of the transformers is a major concern in terms of platform construction and maintenance operations. Additionally, environmental issues have to be assessed as critical. Thus, a transformer-less HVDC would be an eminent advantage. A transformer-less MMC-based HVDC dimensioning is presented taking into account the necessary boost operation.

On Short-Circuit Protection Alternatives in the Scope of HVDC Transmission Applications
Volker Staudt, Andreas Steimel, Ruhr-University of Bochum, D; Carsten Heising, Avasition, D
The role of converters in energy transmission becomes more and more important. The main advantages of IGBT-based solutions are independent active and reactive current control as well as superior performance in case of AC-grid faults. Depending on the topology and the control chosen, faults in the DC grid may be critical. Different MMC topologies are compared basically for DC-fault situations (2q, 2q and DC breaker, 4q).

Passive Components, Sensors, etc

A Novel Optimization Strategy for Point of Load Converters
Christian Oeder, H.Tech, T. Duerbaum, University of Erlangen-Nuremberg, D
Many electrical applications use the buck converter topology as point of load converter to provide the desired output voltage for their loads. While its efficiency is usually optimized for high output powers, in case of low and mid power it is often reduced. Nevertheless, since many applications force these converters to operate at part load condition most of the time, the system's overall power consumption can be reduced noticeably by optimizing the efficiency at its nominal operating point.

Green Energy and Industrial – Film Capacitors Applications
Paola Bettacchi, Davide Orioli, Gianluca Rondelli, Daniele Zanarini, Davide Montanari, Antonio Sanua, Francesco Bergamaschi, KEMET Electronics Corporation, I
Green Energies applications and trend. Film Capacitors development both for high thin PP film, metallization and capacitors production technoloies to meet the new requirements of the market. Last capaciors generation and development.

New Ultra-Load-Dump Crowbar Resistors for Pulsed Applications
Matthias Dreßler, Vishay Electronic, D
With the ULDCR series, Vishay offers a self-supporting, ultra-compact, and highly reliable load-dump or crowbar resistor design for wind and hydro-power converters, where energies up to several mega joules need to be dumped in case of electrical overload.

Energy-Efficient Transformers - Loss Reduced Constructions as a Step Towards a Decreased Energy Consumption
Daniel Mandl, Heinz-Herbert Berger, Tauscher Transformatoren, D
Back in the days the purchase prize of a device was the most significant, today the whole life-cycle cost is of high importance. The topic energy efficiency becomes more and more crucial. To reduce the losses that occur in transformers is an essential part of new developments nowadays.

The Simulation of Copper Losses in Litz-Wire Windings Considering Air Gap Fringing Fields
Alexander Stadler, Raoul Huber, Tobias Stolzke, Christof Gulden, STS Spezial-Transformatoren-Stockach, D
In this paper, a systematic procedure is presented, how to predict the AC resistance of litz-wire windings considering air gap fringing fields. An equivalent complex permeability model is derived for hexagonally packed wires. Finite element method (FEM) is used to determine the complex permeability, to describe the air gap fringing field, the proximity losses of the litz-wire winding and the AC resistance as well. The results are very close to experimental data drawn from impedance measurements.

Novel Approach to Describe the Material Functions of the Hodgdon Model to Match the Hysteresis Behavior of Silicon Iron 6.5 %
Anne-Christine Leicht, Janina Fischer, Manfred Albach, University of Erlangen-Nuremberg, D
This paper provides a polynomial approach applied to the Hodgdon model to describe the Hysteresis Loops of Silicon Iron 6.5 % (SiFe 6.5 %). The approach provides a closed-form expression for the branches of the Hysteresis Loop, which allows extensive parameter sweeps to adjust the parameters. Thus a huge number of variations can be calculated in a short period of time.

Novel Low-Cost Closed-Loop Compensated Current Transducer with Enhanced Performance
Diego Gutierrez, Cyprien Brun, LEM Switzerland SA, CH
A low-cost closed-loop current transducer with enhanced measurement performance is presented.
The working principle, main design choices, FEM simulation results and laboratory test measurement results are explained.
The transducer development process starting from CAD design, continuing with simulations, a prototyping phase, and finishing with tests and measurements to confirm the achievement of the design goals is shown.

Waveforms, Current Sensors and their Bandwidth in Power Electronics
Nicolas Karrer, ETH, CH; Boris Hudoffsky, University of Stuttgart, D
The existence of different types of current sensors, ratings, physical sizes and various bandwidth specifications render it difficult to select a current sensor, which performs accurate measurements.
In this paper, first, different current waveforms are selected and parametrized in the time- as well as in the frequency-domain. Then, the bandwidth, which is needed to measure such waveforms, is discussed. Last, lab measurements are presented to show the discrepancy between ideal and real sensors.

Algorithm for Indirect Load Recognition in Domestic Power Consumption
Nikolai Nikolaev, Angel Marinov, Yulian Rangelov, Technical University of Varna, BG
The paper presents an algorithm for indirect load recognition in domestic power applications. This approach allows a central digital electrical energy meter to register when a member of a pre-given set of electrical consumers is being switched and thus determine its contribution to the electrical energy consumption in terms of total, active and reactive power. The algorithm recognizes electrical consumers based on their specific power signature.

Automated EMI Measurement Set-up Comprising CM and DM Measurements with a Modified LISN
Juergen Stahl, Erika Stenglein, Manfred Albach, University of Erlangen-Nuremburg, D
For a proper EMI filter design it is necessary to measure the noise at all phases. Furthermore, the contribution and distribution of the cm and dm noise is crucial. Hence, it needs to be measured as well. The EMI noise measurement process is operated manually and the measurement set-up has to be adjusted. Hence, the measurement is time-consuming and prone to faults. Therefore, it is very important to automate the process. A novel fully automated EMI measurement set-up is presented here.

Drive and Protection

New System Partitioning for Safe Automotive Inverters
Laurent Beaurenaut, Klaus Scheibert, Infineon Technologies, D
This paper presents a new partitioning for inverter systems, based on the interaction of a digital gate driver, a booster stage and a microcontroller, whose combined functions allow implementing Active Short Circuits strategies with a reduced bill of material.

Active Gate Driver for New Generation of High Power IGBTs: Nice to have or a Must?
Veljko Palija, Petar Grbovic, Huawei Technologies, D
This paper gives an answer on a dilemma: Driving latest generation of high power IGBTs with active ate driver-Nice to have feature or a must
Problem of turn off over-voltage and its effects on the IGBT stress are discussed. From the analysis presented in this paper, we can draw a simple conclusion. It is very difficult to use latest generation of IGBTs driven by simple passive gate drivers! An active gate driver is a “must”, not a “nice to have” feature.

A New High Voltage Half Bridge Driver IC Concept for Consumer Electronics and Home Appliances
Wolfgang Frank, Viktor Boguszewicz, Rolf Buckhorst, Infineon Technologies, D
Only a few half bridge driver IC offer so far integrated bootstrap function for the high side supply due to high additional losses. But the advantages of a powerful integrated bootstrap function are striking: simpler layout, less PCB space and better component placement in terms of distance to the gate terminal of the power transistor. This paper proposes a new bootstrap concept of a half bridge gate drive IC up to 2A supporting design considerations for consumer electronics or home appliances.

On Designing Robust and High Bandwidth Digital Current Controllers for SiC and GaN Inverters
Jens Krah, Heiko Schmirgel, Cologne University of Applied Science, D
High current control bandwidth is necessary to ensure best tracking performance of the current in the presence of uncertainties and to provide means for attenuating system disturbances es-pecially for fast switching low inductance systems. This paper presents an analytic straight for-ward approach to determine the achievable bandwidth as a function of three delay indices: Switching frequency, algorithm processing time and current acquisition delay (phase lag).

Digital Multiphase Constant-on Time Regulator Based on Voltage Controlled Oscillator
Osvaldo Zambetti, Daniele Giorgetti, Alessandro Zafarana, ST Microelectronics, I
Faster processor in a smaller power range has pushed the switching frequency (FSW) of the multiphase regulators to higher values in order to minimize real estate and to match in an easier way the electrical specifications of the processors. In this paper an innovative digital control loop architecture featuring a new PWM modulator will be described; it allows to work at high frequency using ceramic capacitors.

Keynote: Traction Drives, from IGBT modules to Silicon Carbide components
Speaker: Michel Mermet-Guyennet, ALSTOM, F
Power component technologies evolve very fast. In 1995, ALSTOM Transport introduced the first traction drive using IGBT (Insulated Gate Power Component) power components in tramway application; since this date, all the ALSTOM traction drives use IGBT components with blocking voltage up to 6,5 kV. This is the case of the new AGV train which is the last generation of very high speed train with distributed power among all the cars and permanent magnet motors.
In 2008, a new generation of power component based on SiC (Silicon Carbide crystal) has reached industrial maturity and is available up to 1700V blocking voltage today. These components offers much better characteristics than IGBT :
- Very low switching energy (20X lower than IGBT) enabling high frequency operation
- Much higher operational temperature (>200°C possible)
- Possibility to increase component blocking voltage (>20 kV possible).
These components will revolutionize the approach of traction to take the full advantage of their characteristics, leading to a much better integration and efficiency. A prospective view will be presented. However, several aspects are still open and need in depth investigations before starting a commercial implementation.

Wide Band Gap Devices II

Influence of Parasitic Inductances on the Switching Behavior of SiC JFET
Tobias Appel, Hans-Günter Eckel, University of Rostock, D
In this paper, the reverse recovery and the turn–on behavior of the normally on SiC JFET in a Cascode Light configuration is evaluated. Due to switching the gradient of drain to source voltage causes a current through the miller capacitance.
The positive feedback by the stray inductances can decrease the gate voltage before the drain to source voltage is rising in case of reverse recovery. There is a negative feedback on the gate in case of switching. It is slowing down the turn-on behavior.

Gate-Drive Considerations for Silicon Carbide FET-Based Half-Bridge Circuits
Andrew Lemmon, Michael Mazzola, James Gafford, Christopher Parker, Mississippi State University, USA
SiC field-effect devices are known to enable high-performance power electronics applications due to their low intrinsic capacitance and on-resistance. However, non-negligible oscillatory phenomena, including instability, can accompany this increased performance, particularly in applications based on the half-bridge topology. This paper presents an analysis which enables designers to ensure the stability of applications based on this topology through careful management of gate-drive impedance.

Switching Characteristics of 200V Normally-off GaN HEMTs
Sibylle Dieckerhoff, Nasser Badawi, Berlin University of Technology, D; Oliver Hilt, Eldad Bahat-Treidel, Hans-Joachim Würfl, Ferdinand-Braun-Institute of Berlin, D
This work presents the switching characteristics of newly-developed GaN normally-off power transistors. It is shown that the switching capability of the new devices is promising since they have a low gate charge and can operate at very high switching speeds. However, they show increased dynamic on-state resistance. This problem needs to be addressed in order to make the devices available for competitive converter operation.

Low Loss, High Current SiC MOSFET Module
Masashi Hayashiguchi, Mineo Miura, Kenji Hayashi, Nobuhiro Hase, Kazuhide Ino, ROHM, J
This paper presents the methodology to the raise rating current of SiC power modules. The characteristics of SiC MOSFETs enable designers to eliminate SiC SBD chips working as free-wheeling diodes and to replace them with SiC MOSFET chips in parallel. In addition, higher gate resistance and a positive temperature coefficient of on-resistance, gate current and drain current are more easily balanced than Si IGBTs. These facts lead to the realization of low-loss high current power module.

Diode-Free Synchronous Rectification Using a SiC Trench JFET
Michael Mazzola, Robin Schrader, James Gafford, Mississippi State University, USA
A body diode like reverse conduction mode of operation of the SiC trench JFET allows for diode-free synchronous rectification. This reverse conduction mode is an inherent property enabled by modest gate-drain diode forward bias. Experimental results for a synchronous buck converter confirms expectations for a SiC VJFET without internal body diode or external anti-parallel diode. Utilizing this mode minimizes SiC die area and lowers component count for reduced total system cost.

Power Semiconductors Switches I

The Next Generation 6500V BIGT HiPak Modules
Liutauras Storasta, Arnost Kopta, Munaf Rahimo, Charalampos Papadopoulos, Silvan Geissmann, Raffael Schnell, ABB Switzerland, CH
Nominated for the Best Paper Award
The introduction of the Bimode Insulated Gate Transistor (BIGT) technology in the 6500V HiPak module with current ratings reaching towards 900A will be demonstrated. Detailed electrical characterization results of the newly developed modules will be provided highlighting the key performance improvements brought by the new technology: higher output current, uncompromised diode surge capability, soft switching waveforms.

New 3.3kV IGBT Module with Low Power Loss and High Current Ratings
Katsunori Azuma, Akitoyo Konno, Isamu Yoshida, Yasushi Toyoda, Katsuaki Saito, Hitachi, J
New 3.3kV IGBT module was developed. To achieve low loss characteristics, Trench HiGT structure is adopted, and diode characteristics are optimized by lifetime control. These devices show softer switching behavior compared with the present product type. The current ratings of new IGBT module can be increased by 20% from the present product type with these IGBT and Diode characteristic improvement, and structural change with low thermal resistance and low internal stray.

Optimized Buffer Layer for the High Performance and Enhanced Short Circuit Immunity of Trench IGBT
Kyu-Hyun Lee, Young Chul Kim, Kyung Suk Park, Bong Yong Lee, Young Chul Choi, Fairchild Semiconductor, ROK
Nominated for the Best Paper Award
In this work, multiple buffer layers are adopted for the optimized field blocking in off state and effective minority carrier injection control under on state of IGBT.
650V Field Stop trench IGBT has been developed, achieving remarkably better performances as well as reliable oscillation free ruggedness under short circuit condition by optimizing multiple buffer layers, comparing conventional Field Stop IGBT.

Next Step Towards Higher Power Density with New IGBT and Diode Generation and Influence on Inverter Design
Alexander Ciliox, Klaus Vogel, Franz-Josef Niedernostheide, Andreas Haertl, Infineon Technologies, D
In this paper we present the achievable level of power density increase based on the new 1200V IGBT and diode technology. Besides this the importance of the inverter's thermal design on the ability to provide the higher power density with new module packages is presented and discussed.

Special Session "E-Mobility Charging Systems"

Self-oscillating Power Converter for an Inductive Charging System
Marco Zimmer, Jörg Heinrich, University of Stuttgart, D
The paper discusses the use of a self-oscillating power converter with parallel compensation for the stationary part of a contactless charging system for electric vehicles. Here, the basic characteristics of a primary-side parallel-compensated power transmission system will be considered, as well as a comparison of the system with a series-compensated system.

Characterization Of Large-Air-Gap Transformer Systems By Two-Port-Theory
Thomas Komma, Monika Pöbl, Siemens, D

A Coil System Optimisation for Contactless Inductive Energy Transmission
Sven Thamm, Christian Rathge, Ulrich Jumar, Institute of Automation and Communication, D
For the inductive power transmission (IPT), an electromagnetic simulation tool connected to an optimisation algorithm is used to design coil geometries that have enhanced coupling tolerances regarding angular and lateral misalignment. This paper exemplarily compares two different coil systems for contactless inductive power transmission for industrial, domestic and medical applications.

Comparison of Planar and Solenoid Coil Arrangements for Inductive EV-Charging Application
Faical Turki, Daniel Kuerschner, Chris Yotta, Paul Vahle, D; Sven Thamm, Christian Rathge, Institute of Automation and Communication, D
To meet the safety and efficiency requirements of inductive EV-charging systems that are defined in International technical proposals, the magnetic assembly has to be designed very well. In the presented work possible coil arrangements are investigated and compared. Therefore the parameters magnetic coupling, EMF and power loss are taken into account. Pros and cons of coil arrangements are discussed and inductive EV-charging systems (via number plate or bottom side of the car) are presented.

Special Session “Wind Energy Technology”

Generators/Drive Systems for Wind Turbines
Bernd Ponick, University of Hannover, D
Currently, there are different types of generators/drive systems for wind turbines in use. The differences refer mainly to the general layout with directly driven generator, medium speed generator (some 100 rpm) or high speed generator (around 1500 ... 2000 rpm) and to the principle of electromagnetic power conversion (PM synchronous generator vs. electrically excited synchronous generator vs. doubly fed induction generator vs. cage induction generator).

Medium Voltage Power Conversion for Windpower
Peter Steimer, Oscar Apeldoorn, Luca Dalessandro, Roman Grinberg, Stephan Ebner, ABB Switzerland, CH

Power Converters for Low Voltage Medium Power Wind Turbines
Frank Springmeier, Stephan Engelhardt, Woodward Kempen, D
Power converters are a key component in todays wind turbines. Medium power wind turbines up to 4 MW rated power are equipped with low voltage converters. There are full power converter systems feeding permanent magnet or field excited synchronous machines as well as systems feeding doubly fed induction machines. The actual state of technique of these converters is presented and future trends are evaluated. The converter design including power semiconductor stress and impact of new power semiconductor concepts will be covered in the presentation.

Challenges in Grid Integration for Wind Energy Converters
Yusuf Gündüz, Siemens, D
Converters are a core component of wind mills. They have to comply with various regulations when supplying electrical energy to the grid. The market demands various different regional standards and grid codes. Furthermore, these requirements are changing quickly.
A trend can be identified that more and more converters will be connected to the grid as energy sources. Therefore, grid stability is already a challenge now and will be even more in the future.

Power Electronics in Automotive, Traction and Aerospace

Power Modules with Embedded Chips for Automotive Applications
Andreas Ostmann, Lars Boettcher, Fraunhofer IZM, D; Thomas Hofmann, Continental, D; Christoph Neeb, RWTH Aachen University, D; Rainer Kuschke, Dionysios Manessis, Klaus-Dieter Lang, Technical University of Berlin, D
A new technology for automotive power inverters is under development in a German R&D initiative. Instead of wire-bonded chips in DCB-based modules components are embedded in PCB structures. The embedding enables a planar packaging with very low inductances and a double-side cooling capability. The development steps towards a 10 kW inverter module with embedded IGBTs and diodes will be described. The process steps and reliability investigations of the different interconnect levels will be shown.

Decentralized Electromotive Drive Train System Using Extra Low Voltage
Thomas Szalai, Ulf Schwalbe, Tobias Heidrich, Fabian Endert, Svetlozar Dimitrov Ivanov, Ilmenau University of Technology, D
A decentralized electromotive drive train system using extra low voltage is presented. The system has good compatibility with the 48V power-supply-system currently in discussion for all vehicles. It allows for scaling to different electric vehicles by varying the number of 25kW-units used. It is a closed system that can manage the dynamic power flow caused by acceleration and braking for a given time without assistance from the main battery.

Transformer Optimisation of the Integrated AC/DC–DC/AC Bidirectional Converter for Vehicle to Grid Interfacing
Ashot Melkonyan, Kai Kriegel, Siemens, D; Jiabin Wang, Khoa Dang Hoang, University of Sheffield, UK; Roman Nestlinger, UAS Germany, D
Design of the 2.5kW Vehicle to Grid (V2G) Interfacing integrated AC/DC–DC/AC bidirectional converter and its power transformer optimisation.

Active Power Filter for Aerospace Application: Implementation and Validation of Control Algorithm in two DSP Controller Board
Sebastian Liebig, Liebherr Elektronik, D
The intentions of the More Electrical Aircraft (MEA) concept are weight reduction and higher efficiency by application of more electrical systems. Conventionally, power electronic devices apply 12-pulse autotransformers to rectify the 360 to 800 Hz supply. An interesting alternative is the parallel active power filter (APF), which compensates for the 5th and 7th harmonics. This paper presents the implementation of the control algorithm into two DSPs and evaluates the performance by measurements.

New Power Electronic Building Block

COOLiR2DIE(tm) Technology: A Building Block for High Power Automotive HEV and EV Inverter Applications
Mark Pavier, Stuart Cardwell, Scott Palmer, Andrew Sawle, International Rectifier, UK; Dee Bunna, Henning Hauenstein, International Rectifier, USA
Automotive hybrid and electric vehicle inverter applications demand a packaging technology that accommodates large, ultra-thin power semiconductor die, switch high currents with minimum noise, reliable in operation and efficiently transfer heat to the system heat sink. COOLiR2DIETM is a new power device packaging technology for use in high power inverter applications. Details of package construction, thermal resistance and electrical performance are discussed.

New Assembly Technologies for Tjmax=175°C Continuous Operation Guaranty of IGBT Module
Takashi Saito, Yoshitaka Nishimura, Kazumasa Kido, Fumihiko Momose, Eiji Mochizuki, Yoshikazu Takahashi, Fuji Electric, J
One of the major problem for Tjmax=175°C operation is decreased reliability caused by higher temperature. Especially, dTj power cycling (P/C) capability is decreased. The purpose of this study is to reveal the failure mechanism when operated at Tjmax=175°C and to verify conceivable countermeasures. We found out the limit of the reliability of the technologies such as Al wire bonding and soldering. As a result we achieved at Tjmax=175°C, twice the conventional P/C capability at Tjmax=150°C.

Power Module Design for an Ultra Efficient Three-Level Utility Grid Solar Inverter
Michael Frisch, Vincotech, D; Ernö Temesi, Vincotech, HU
The race to achieve highest efficiency had engineers leveraging innovative topologies and new components such as SiC to take the lead.
The new power module design presented here transcends the limitations associated with 100 kW+ power inverters to accommodate high switching frequencies and innovative topologies. Based on standard Si components, this new solution uses parasitic inductance and applies the basic rules of power electronics to boost the performance of conventional designs.

Electrical, Thermal and Electromagnetic Design of a SiC Solar Inverter: a Case Study
Eckart Hoene, Stefan Hoffmann, Oleg Zeiter, Fraunhofer IZM, D
Designing power electronics is an interdisciplinary task. In this paper a 15 demonstrator to evaluate the help of simulation tools during the design process. The optimization of the inverter is described as well as modifications of the tools were derived and tested.

Multi-Level Converter and Gate Drive

Performance Evaluation of Different Carrier-based Modulation Strategies in Modular Multilevel Converter
Xudan Liu, Andreas Lindemann, Yuwei Zhou, Otto-von-Guericke-University of Magdeburg, D
The modular multilevel converter is attracting more and more attention in the area of high-power high-voltage applications. Various control and modulation methods have been proposed to improve the performance of MMC. This paper presents an evaluation of different carrier-based modulation strategies in MMC. Four different carrier-based modulation strategies are compared both in theory and simulation results. The presented investigation provides an instruction for selecting modulation methods.

Methods of Generating Gate Drive Bias Power Rails for IGBT Motor Drive Inverters
Bob Zwicker, Analog Devices, USA
This paper explores bias rail generation topologies for IGBT Motor Drive Inverters
and the advantages and disadvantages of each. Several will be presented with test data. Conclusions will be technique recommendations.

Hybrid Modulation Method for Three-Level Inverters in Renewable Energy Applications
Yann Lissillour, SEMIKRON, F; Jonathan Dodge, SEMIKRON, USA
Hardware design and modulation method for three-level inverters are inseparable. Existing modulation methods trade switching loss and output harmonics against 3rd harmonic neutral point current, which greatly affects the size of the capacitor banks and hence cost. A proposed hybrid modulation scheme mixes two PWM methods: symmetric nearest three vectors (NTV) and nearest three virtual vectors (NTV2). The mixing strategy optimizes tradeoffs for renewable energy applications based on modulation index, electrical angle, and power factor. Neutral point balancing in all modes of operation is explained. Experimental results are presented.

Special Session "E-Mobility – Power Train"

Comparison of Conventional and Innovative Converter Topologies for Electric Car Applications
Mirjam Mantel, Siemens, D
All-electric drivetrains are becoming more and more important for future mobility concepts. These applications impose specific requirements and offer attractive possibilities of optimization. The specific requirements regarding the converter technology include high efficiency – especially at part load, high power-density and high output-frequencies. This paper compares innovative and conventional converter topologies and assesses their suitability for electric vehicle applications.

Static Load Test of Vehicle Inverters without Active Power Throughput
Yusuf Uslu, Ulrich Ammann, Daimler, D; Nejila Parspour, University of Stuttgart, D
For the qualification and quality assurance of inverters in electric vehicles specific tests have to be accomplished. The presented procedure as well as the experimental setup realizes a simple, non-destructive test of electric motor inverters at about 1 % of the rated power throughput. The high complexity of a common test at rated output power is avoided by a series of DC static load tests which do not need any load, modulation or feedback control.

An Efficient Approach to Specify the Cooling System in Electric Powertrains with Presumed Drive Cycles
Johannes V. Gragger, Thomas Bäuml, Dragan Simic, Austrian Institute of Technology, A
In this work the interactions of the cooling system with the inverter and machine of an electric bus are assessed. A vehicle model is applied for the calculation of the torque and speed of the machine. These results are then imported in an electro-thermal-mechanical powertrain model that is fast enough to calculate the thermal conditions in the powertrain throughout an entire drive cycle. With a refined model the (cooling system dependent) maximum semiconductor temperatures are calculated.

Power Electronics in Transmission Systems

A new HVDC-DC converter for the efficient connection of HVDC networks
André Schön, Mark-M. Bakran, University of Bayreuth, D
Nominated for the Best Paper Award
In the future European energy grid, HVDC energy transportation becomes more and more important. Hence, the economic interconnection of HVDC links with different voltage ratings will be fundamental to a working HVDC grid. In this paper a new HVDC-DC Converter based on M2C technology is introduced, its functional principle is analyzed and its characteristics are compared with the direct method of connecting two HVDC links through an AC coupling.

Multivariable Pole-Restraining Control of MMC-based HVDCs under Dynamic Operation
Carsten Heising, Tim Schrader, Roman Bartelt, Avasition, D; Volker Staudt, Andreas Steimel, Ruhr-University of Bochum, D
Nominated for the Best Paper Award
A body diode like reverse conduction mode of operation of the SiC trench JFET allows for diode-free synchronous rectification. This reverse conduction mode is an inherent property enabled by modest gate-drain diode forward bias. Experimental results for a synchronous buck converter confirms expectations for a SiC VJFET without internal body diode or external anti-parallel diode. Utilizing this mode minimizes SiC die area and lowers component count for reduced total system cost.

Operation of Modular Multilevel Converter and DC-Breaker in large Multiterminal-HVDC-Grids
Yeqi Wang, Rainer Marquardt, University of the Federal Armed Forces Munich, D
Nominated for the Best Paper Award
A large meshed HVDC-SuperGrid has been proposed by several experts as the best solution. With DC-transmission being neglected for a long time, many essential requirements, especially availability and reliability have to be researched thoroughly. The following paper deals with the requirements of the main components (Modular Multilevel Converters and DC-Breakers) in large meshed grids with focus on their fault handling abilities.

System Reliability

Fault-Tolerant Flying Capacitor Multilevel DC/DC-Converters
Michael Gleissner, Mark-M. Bakran, University of Bayreuth, D
The Flying Capacitor Multilevel DC/DC-Converter offers an interesting approach for continuative operation after a single fault for applications with high availability requirements. In case of a single short-circuited semiconductor switch a degraded operation is possible. Potential fault scenarios are studied. Moreover fault detection, isolation and reconfiguration algorithms are presented and implemented in simulations and a prototype. Furthermore fault-tolerant design aspects are considered.

Application Based Modified Reliability Tests and their Physical Correlation with Lifetime Assessment Models
Indrajit Paul, Laurent Beaurenaut, Frank Sauerland, Marina Stoilkova, Infineon Technologies, D
Lifetime assessment models for IGBT based power modules used in electric drive applications are extremely useful for preliminary dimensioning and selection of the associated system. During real application environment the overall load/stress is usually a combination of these tests with varied durations. Consequently fundamental understanding of the mapping between reliability tests and field application is extremely important.

Reactive Power Impact on Lifetime Prediction of Two-level Wind Power Converter
Dao Zhou, Frede Blaabjerg, Aalborg University, DK; M. Lau, M. Tonnes, Danfoss Silicon Power, D
In this paper, effects of reactive power to typical wind power converter (DFIG-based partial-scale and PMSG-based full-scale) is addressed and compared. The injection of the reactive power could have serious impact to power loss and thermal performance of both configurations, especially at lower wind speed. Furthermore, the introduction of the reactive power could also shorten the lifetime of the wind power converter significantly.

Poster/Dialogue Session

Converters I

A Review of the Series Resonant Converter Operating in the Capacitive Side of the ResonantCurve in Domestic Induction Heating Application
Cesare Bocchiola, Jorge Cerezo, International Rectifier, I
Induction heating (IH) technology is well-known in domestic cooking thanks to its superior energy efficiency. The series resonant converters are mostly used, driven with variable frequency control in the inductive side of the resonant curve. This paper discusses significant benefits of capacitive side control scheme: by using the optimal IGBT and Diode better efficiency, lower EMI and higher reliability performances can be achieved.

Increasing of the Utilization of the DC-Voltage of the Three Phase Four Leg Inverter
Ismael Shakra, Thomas Ellinger, Ilmenau University of Technology, D
This paper describes a control method for increasing the utilization of the DC-voltage of the 3-Phase 4-Leg Inverter. This objective can be achieved using 150 Hz. It leads to high Dynamism and protection of the semiconductor device from blocking voltage. It also helps in decreasing the switching loss. The work presents theoretical study for the suggested idea that is simulated. Finally, there is a practical application in a 3-phase 4-leg active Filter.

Optimal Control Tuning of Grid Connected Voltage Source Converters using a Multi-Objective Genetic Algorithm
Rodrigo Teixeira Pinto, Sílvio Fragoso Rodrigues, Pavol Bauer, Delft University of Technology, NL; Jan Pierik, ECN, NL
Given its capabilities, voltage-source converters will likely constitute the basic building block for the AC/DC conversion in future smart grids and HVDC supergrids. This work seeks to optimize the control tuning of VSCs by using a multi-objective genetic algorithm. The optimization is performed on a small-signal model which includes the converter hardware and complete control. The results are tested in a 5-kVA converter and measurements are compared with the non-linear and small-signal models.

Design of Interleaved Power Converters under Volume, Efficiency and Thermal Constraints
Mahraz Bendali, Cherif Larouci, Toufik Azib, ESTACA Engineer School, F; Claude Marchand, University of Paris, F; Gerard Coquery, The French Institute of Science and Technology for Transport, Development and Networks, F
This paper deals with an approach to design interleaved static power converters. This approach is based on an optimization under multi-physic constraints procedure considering the number of cells of an interleaved converter as a key design parameter. The proposed method is applied to 42V-14V interleaved buck converter for automotive on-board network. It allows establishing the converter architecture by deterring its optimal number of cells while considering multiphysics constraints.

A Novel Digital Control System for Direct Paralleling Power Supplies
Qingyi Huang, Renjian Xie, Yingyang Ou, Analog Devices, CN
These papers proposed a new digital controlled method which eliminates OR-ing circuit, solves the problems in direct parallel power supplies, improves the overall efficiency, reduces the overall board size and reduce overall cost in the application of paralleling power supplies.

PFC Topology Selection and Design for Professional Applications
Stefan Schmitt, Jens Marten, BLOCK Transformatoren-Elektronik, D

A Novel Detailed Analysis of the Series Resonant Converter with Inductive Output Filter
Christian Oeder, Erika Stenglein, Thomas Düerbaum, University of Erlangen-Nuremberg, D
Within the present trend towards miniaturization and higher power densities, smaller passive components together with higher switching frequencies are desired. In combination with new market requirements (e.g. LED drivers), there is an upcoming trend for resonant converters with inductive output filter. But since it is rather difficult to design reasonable high inductance values for the output coils, the assumption of a constant current source at the output is not justified in most cases. As a consequence, this paper introduces a novel, detailed analysis of the series resonant converter incorporating finite values for the output inductance. To the author's knowledge, it is the first time that the influence of the finite value is included in the investigation of this converter.

Balancing Energy Losses in Parallel Connected MOSFETs for Push Pull Inverters
Nikolai Nikolaev, Vencislav Valchev, Borislav Dimitrov, Alex van den Bosshe, Technical University of Varna, BG
The paper suggests an approach that allows energy loss balancing in parallel connected MOSFETs for a push-pull inverter. This balancing is obtained trough parallel connection of the MOSFETs trough a multifilar primary winding instead of a conventional direct parallel connection. Experimental results carried out for the suggested topology show better thermal distribution on the surface of the MOSFETs which results in elimination of insulated areas with peak temperatures.

Multichannel High-Power High-Frequency Converter for Induction Heating
Daniel Montesinos-Miracle, Guillermo Martín-Segura, Pau Sala-Pérez, CITCEA-UPC, ES; Coia Ferrater-Simón, Joaquim López-Mestre, CINERGIA, SCCL, ES
This paper studies a converter structure based on the connection of basic topologies to form a multichannel converter for induction heating applications. The aim of this study is to consider topologies that provide a reduction of design time and cost, reduction of the cost derived from higher volume production, reduction of stock components and reduction of installation and maintenance work.

Converters II

Design and Practical Evaluation of a Power Regeneration System for Voltage Source Converters
Johann Austermann, Holger Borcherding, University of Applied Sciences Ostwestfalen Lippe, D; Joachim Böcker, University of Paderborn, D
In this paper a new circuit for feeding back braking-energy from dc-link-converters is shown. The circuit, consisting of a buck converter and a synchronous rectifier, can be connected to the DC-link or the brake chopper connectors and the mains. It is an advantage over active front end converters that, in supply mode, the usual used bridge rectifier can be preserved. As the new circuit has to be designed only for the regenerative power, this is an cheap efficient solution.

Increased Coil-Capacitance for Zero-Voltage-Switching in Resonant-Converters
Reinhard Jaschke, Klaus F. Hoffmann, Helmut Schmidt University of Hamburg, D
The capacitance of an inductive coil can be increased by a special connection of the coil layers. An application for this is the resonant load of a Compact Fluorescent Lamp (CFL) with Zero-Voltage-Switching which can be driven without an extern du/dt-capacitor. By this, the bill of material is clearly
reduced. In the final paper the calculation of the coil capacitance will be presented and measurements of the coil current and voltages will be analyzed and compared with simulations.

690 V line side inverters with improved reactive power capability
Hans-Guenter Eckel, Daniel Wigger, University of Rostock, D
The 690 V line is a preferred voltage level for wind energy and photovoltaic inverters. Two level voltage source inverters with 1700 V IGBT are commonly used. In this paper it is shown, that they have only limited reactive power capability in overexcited operation. It is suggested to develop 2000 V IGBT for these applicationsor to use 1200 V IGBT in a three level configuration. Both solutions would allow a very robust inverter design with a high reactive power capability.

Accounting of PWM Control and Connecting Elements on Three-phase Inverter for Quick and Precise DC Link Sizing Using a Numerical Method
Yann Lissillour, SEMIKRON, F
This paper proposes to analyze the dc link ripple currents for three-phase back-to-back parallelized PWM converters. First, the inverter currents are discussed only considering the switching function for RMS and frequency domain. The effect of parasitic elements of capacitors and busbars is studied through the determination resonance frequencies of capacitors banks and its effect on ripple currents. A numerical tool is developed for fast and precise calculation.

Comparison of Thyristor Rectifier with Hybrid Filter and Chopper-Rectifier for High Power, High Current Application
Jitendra Solanki, Joachim Böcker, Norbert Fröhleke, University of Paderborn, D; Peter Wallmeier, AEG Power Solution, D
This paper presents a comparison of two rectifier systems for high power and high current applications. An entire system level approach is chosen for comparison of 12-pulse thyristor rectifier with hybrid filter and 12-pulse diode rectifier with dc chopper. Comparison is carried out in terms of system performance, efficiency and size, for a particular type of industrial load with given system requirements

Investigation of the Forecast of Radiated Electromagnetic Emissions of Power Converters Using Switching Waveform Analysis
Julia Bauch, Sebastian Schulz, Andreas Lindemann, Moawia Al-Hamid, Ralf Vick, Otto-von-Guericke-University of Magdeburg, D
Investigation of the forecast of radiated electromagnetic emissions of power converters using switching waveform analysis

Prediction of Conducted EMI in Power Converter with front-end Three-phase Diode-bridge in Frequency Domain
Junsheng Wei, Dieter Gerling, University of the Federal Armed Forces Munich, D; Marek Galek, Siemens, D
Prediction of Conducted EMI in Power Converter with front-end Three-phase Diode-bridge in Frequency Domain

Minimization of Low Side IGBTs Turn on Switching Loss by Simple External Circuitry
MinSub Lee, JunHo Lee, JunBae Lee, DaeWoong Chung, LS Power Semitech, ROK
Many of senseless motor control system use external shunt resistors at low side IGBT emitter to measure output current easily. Low side IGBT turn on switching loss is larger than high side IGBT turn on switching loss since stray inductance of internal terminal of module, external shunt resistor and PCB pattern between gate drive IC ground and low side IGBT emitter. In this paper, it will be explained that how to minimize low side gate voltage drop effectively by using simple additional circuitry

Ground Fault Detection Method for Three Phase PWM Variable Speed Drives
Petar Grbovic, Huawei Technologies, D
This paper discusses and proposes a new method for detection of ground short circuit fault in pulse width modulated (PWM) variable speed drives (VSD). The proposed detection method is based on measurement of the common mode flux of the dc filter inductor. Two sensing windings are added on the inductor, and voltage induced across the added windings is measured and processed by the analog/digital detection circuit.

DC-DC converters

Hybrid Control Method for Optimal Transient Response and Output Filter Minimization for Buck-Boost type Converters
Mor Mordechai Peretz, Ben-Gurion University, IL

Experimental Analysis of Wide Input Voltage Range qZS-derived Push-Pull DC/DC Converter for PMSG-based Wind Turbines
Oleksandr Husev, Andrei Blinov, Dmitri Vinnikov, Andrii Chub, Tallinn University of Technology, EST
In this paper the simulation and experimental analysis of a novel qZS-derived step-up push-pull DC/DC converter with a wide input voltage range is presented. The proposed converter is intended for applications that require a high gain of the input voltage and galvanic isolation, i.e. power conditioning systems for alternative energy sources such as photovoltaic panels of fuel cells.

Study of 3-phase DC-DC Converter for Supercapacitor Charging
George Kraev, Nikolai Hinov, Dimiter Arnaudov, Nikola Gradinarov, Nikolai Rangelov, Technical University of Sofia, BG
In the present paper is studied 3-phase DC-DC converter for charging supercapacitors or batteries. Equations for designing the power circuit of converter are also shown. The a.m. equations are confirmed by simulation and experiment in laboratory model.

A Non-isolated DC-DC Converter with InterCell Transformer for Buck-type or Boost-type Application Requiring High Voltage Ratio and High Efficiency
Nicolas Videau, Thierry Meynard, Guillaume Fontes, Didier Flumian, LAPLACE - University of Toulouse, F
In this paper, a non-isolated DC-DC converter for applications requiring high voltage ratio and high efficiency is developed. The topology is based on a non-standard association of commutation cells. We introduce a magnetic coupling of all phases to improve the converter efficiency and increase the power density. The coupled and uncoupled inductors solutions will be discussed and illustrated (Fuel Cell application) with a focus on the reduction of losses and weight of the magnetic component.

A Reversible High Gain DC-DC Buck-Boost Converter For Application in Micro-Grid with DC Bus
Fernando L.M. Antunes, Derivan D. Marques, René P.T. Bascopé, Italo F. Marinho, Paulo M. Teles, Edilson Mineiro Jr., Federal University of Ceara, BR
This paper presents a high voltage gain bi-directional converter to connect a 48V battery bank, to a 311 VDC bus, and stabilize da 311dc bus at the rated voltage, as part of a microgird with DC and AC distribution buses. Experimental results are presented to validated the proposed converter.

Impact of the MOSFET Parasitic Capacitances on the Performances of the LLC Topologies at Light Load
Luigi Abbatelli, Antonino Gaito, Giovanni Ardita, STMicroelectronics, I
This article investigates about the impact of the MOSFET parasitic capacitances on resonant topologies

Parallel buck converter with non-identical power module for improved transient efficiency
Chi Tsang, Martin Foster, David Stone, University of Sheffield, UK
This paper describes a new control methodology to improve the efficiency of a parallel connected buck converter during transient conditions, without unduly increasing the transient response. This is achieved by minimising the on-duration of the high-bandwidth power module of the parallel connected buck converters. The calculated efficiency during the transient condition is shown to improve by as much as 60% dependent on the load condition. A 35W prototype converter is built and its efficiency was measured to be 1.8% higher at step load of 2.4A.

Electromobility

Gate Oxide Defectiveness Levels: an Experimental Comparison between Planar and Trench Low Voltage Power MOSFET Technologies
Salvatore La Mantia, Giuseppe Consentino, STMicroelectronics, I
Gate oxide reliability of Power MOSFETs strongly depends on their defectiveness levels. Higher defectiveness levels could involve in higher gate leakage current, threshold voltage shift effects and lower oxide reliability. Therefore, it is important to evaluate gate oxide defectiveness. This paper estimates the different oxide defectiveness levels of two main topologies utilized in Low Voltage Power MOSFETs and it shows how the Trench compared to the Planar oxide shows higher defectiveness level

Matching the HF Transformers to Contactless Charging Converter for Electric Vehicles
Nikolay Madzharov, Anton Tonchev, Technical University of Gabrovo, BG
One of the fastest growing trends in the automotive industry in recent years is the increasing presence of electric vehicles. The advantages that they have regarding the environmental and economic perspectives are discussed repeatedly. Great progress on solving the problems of energy infrastructure use and the final price is expected in the future. One of the major problems that have to be solved by producers and consumers is the cycle and speed of charging.
This article examines one of the future methods for charging – contactless charging, and in particular, how to coordinate the two-component HF transformer to different types of power converter.

Design and Dimensioning of a Highly Efficient 22 kW Bidirectional Inductive Charger for E-Mobility
Benriah Goeldi, Stefan Reichert, Johannes Tritschler, Fraunhofer ISE, D
This talk discusses the optimal design and dimensioning of a 22 kW bi-directional inductive charging system for electric vehicles.

Full Bridge Interleaved Phase Shift Zero Voltage Switching Converter for Fuel Cell Vehicles
Matthias Tauer, Finepower, D; Michael Patt, UAS Kempten, D
With automobiles getting more and more electrified, there is a large number of different applications where dc/dc-converters have to be placed. In new electric vehicle concepts it is necessary to connect two different voltage levels with galvanic isolation and assure power transfer with high efficiency. The presented paper describes a new approach to improve the advantages of the well known phase shift zero voltage switching (ZVS) converter to meet efficiency and volume requirements.

Re-Conceptualization of the Relationship between Efficiency and Cost in Automotive Industrial Power Converters
Alexander Isurin, Alexander Cook, Vanner, USA
This presentation will show the relationship between topologies of power converters with output power of 2kW and more, and their cost in contemporary environmental and practical recommendations how to get a good and cost effective design for automotive industry. The discussion involves a comparison of different topologies and focuses on the application of the converter in hybrid and other vehicles. All this will be based on author's development experience.

4kW Fully Digital Dual Interleaved Boost Converter as MPPT Controller for Solar Panels in Solar Airship
Mariusz Kowalczyk, Andrea Vezzini, Irene Kunz, Bern University of Applied Sciences, CH; Lech Grzesiak, Warsaw University of Technology, PL
The authors of this article propose a solution of Dual Interleaved MPPT controller, which combines three of the most important features for aerospace application: energy density, efficiency and reliability. The MPPT controller is composed with of redundant boost converters controlled by independent microcontrollers which exchange the information through CAN bus each other. Each boost converter is built as 2-legs interleaved converter. The synchronous rectification and ZVS technique were used.

Comparative Study on Optimal Core Design for Maximizing the Coupling Coefficient in Electric Vehicle Inductive Power Transfer Systems
Marinus Petersen, Friedrich W. Fuchs, Christian-Albrechts-University of Kiel, D
Inductive Power Transfer (IPT) systems are a promising solution for safe and comfortable battery recharging. To maximize the IPT system efficiency it is essential to achieve highest coupling between primary and secondary coil. In this contribution a comparative study of the two main types of core designs (circular single-sided and rectangular double-sided cores) is performed. A conclusion is given which core design is the best choice for given circumstances in IPT systems.

Renewable Energy

Offshore Wind Park AC Grids with Higher Frequency
Sidney Gierschner, Hans-Günter Eckel, University of Rostock, D
The use of HVDC for power transmission becomes more and more important for new offshore wind parks. State of art is a 50Hz offshore distribution grid. The DC-connection decouples the offshore grid and the onshore grid, so frequency becomes a degree of freedom for offshore wind parks. In this paper the effects of a frequency higher than 50Hz on the main components of an offshore wind park are investigated. The pros and cons and the limitations of a higher offshore frequency are presented.

Influence of Variable DC Link Voltage for Grid Side VSC Control Techniques in Terms of Current Harmonics
Magdalena Schröder, Hans-Günter Eckel, University of Rostock, D
Wind power plants often use VSCs to feed energy into public grid. Minimal required dc link voltage at majority of operating points is significantly lower than commonly used fixed voltage. This paper explains theoretical advantages of VFDPC compared with conventional VOC in terms of harmonics, if a reduced dc link voltage is used. Simulation results with Matlab/Simulink show that it is even possible to do without an LCL filter for grid currents.

A numerical technique for PV modules diagnosis
Patrizio Manganiello, Second University of Napoli, I; Giovanni Spagnuolo, Giovanni Petrone, Vincenzo Ricciardi, University of Salerno, I
Diagnostic functions for modules in the string are becoming a key factor in PhotoVoltaic (PV) systems. The possibility of detecting malfunctioning of PV modules is of fundamental importance for avoiding to suspend the power production of the plant or of a part of it because of a failure. In this summary a numerical technique that is able to give an information about the modules operation starting from the knowledge of the voltage at which the panel's modules work is proposed.

A Novel LC Resonant Based Partial Booster Scheme for Improved Efficiency and Reduced Cost of Transformerless Photovoltaic Inverters
Krishna DVMM, Heiko Preckwinkel, Norbert Fröhleke, Joachim Böcker, University of Paderborn, D
Traditionally, Efficiency has been given the top priority for photovoltaic inverters. However, another driving factor in photovoltaic inverter research has been cost reduction. Non isolated three phase inverters have come into the competition mainly to address this issue of cost reduction. This paper presents a new resonant based DC/DC converter control strategy for three phase PV inverter systems, in the sub 50 kW range. The proposed scheme has advantages of easy control, improved efficiency an

Residential Applications of PV-Systems with Energy Storage
Nicola Femia, Massimiliano De Cristofaro, Davide Toledo, Walter Zamboni, University of Salerno, I
Energy management strategies for PV systems with battery storage are discussed, with particular reference to the problem of the daily allocation of deferrable load. The problem is discussed with particular reference to a residential application.

Power Conditioning System with New MPPT Control for a Grid-Connected PV Power Generation System
Kazutaka Itako, Kanagawa Institute of Technology, J
This paper investigates applying the new MPPT control method to power conditioning system (PCS) in a grid-connected type PV power generation system. The experimental results clearly demonstrate that the developed PCS offers outstanding effectiveness in partially shaded environments.

Modular Customer-end Inverter for an LVDC Distribution Network
Aleksi Mattsson, Pasi Nuutinen, Tero Kaipia, Pasi Peltoniemi, Pertti Silventoinen, Jarmo Partanen, Lappeenranta University of Technology, FIN
The LVDC network is used as the last part of the public distribution network preceding the interface to end-users installations. In this paper, a modular three-phase customer-end inverter (CEI) comprising of single-phase inverter modules for the Low-Voltage DC (LVDC) network is studied and modules with different power classes were compared. Different transistor topologies and two output filter topologies were compared and their losses were calculated using a load-curve of true household loads.

AC-Battery with Active Harmonics Compensation
Karl Edelmoser, Felix Himmelstoss, Technical University of Vienna, A
In renewable energy applications, UPS and small islanding applications, smart storage systems become more and more essential. Unfortunately with the rising complexity of electronic systems, the sensitivity to mains harmonics and EMC in general is important. In common single-phase inverter applications the generated current of the inverter shows a large ripple which has to be filtered and smoothed. This has two significant disadvantages: Reduced over all-efficiency due to dynamic maximum power point mismatch and reduced lifetime of the panels due to additional component stress in case of battery and solar applications. Furthermore, the output of the inverter also shows significant distortions in it's voltage and current shape. The proposed approach discussed in this paper uses a so called AC-battery combined with an active filter to fulfill the given requirements: Minimized input current ripple of the cells, optimized maximum power point tracking, optimal power quality, and extended reactive power of the supplying grid.

Multivariable Control of DFIG in Converter-Fixed Reference Frame Including Back-to-Back Converter
Matthias Seifert, Carsten Heising, Avasition, D; Volker Staudt, Andreas Steimel, Ruhr-University of Bochum, D
Three-level NPC inverters present an interesting alternative for grid connection of renewable energy and similar applications. The pole-restraining control approach is adapted taking the time-variant characteristics into consideration and removing the inherent instability to achieve an improved dynamic behaviour. Furthermore, it allows balancing of the DC-link voltages in case of the three-level NPC inverter. The capability of the control approach is demonstrated for two AFE in B2B topology.

Application Oriented Photovoltaic-hybrid system test-bed with battery, hydrogen and heat storage path
Martin Paulitschke, Thilo Bocklisch, Michael Böttiger, Chemnitz University of Technology, D
The paper presents an application oriented PV-hybrid system topology integrating a commercial lithium-ion battery system, hydrogen electrolyser, fuel cell and storage as wells as an electrical heating cartridge with hot water storage. Results of theoretical and experimental investigations demonstrate the beneficial short- and long-term storage, peak shaving and grid stabilzing capabilities of the proposed intelligent decentralized power supply unit.

Energy storage, smart grid

Sensitivity Analysis of the Required Battery Mass for Applications with Constantly High C Rates, Based on a Parametrical Model of a Lithium-Ion Cell
Bastian Liebelt, Mark-Matthias Bakran, University of Bayreuth, D
In applications with constantly high c-rates, the necessary battery mass depends not only on the required energy, the losses and the energy density of the used cell, but also on the ability of the cell to provide the application with the requested power at different boundary conditions and within their operating limits. In this paper the influence of different parameters of a lithium-ion battery model on the overall cell mass will be analysed.

Aspects for the Design of Electrical Protection Components in Energy Distribution Networks
Dirk Leber, Andreas Funcke, Oliver Wittich, LEBER, D
When developing a circuit breaking device success depends on the consideration of a number of technical and regulatory design aspects. The design of electronic circuit breaking systems becomes more and more attractive when combining different modes of protection and integrating additional monitoring functions into the same module. This article discusses the most important design aspects and criteria when selecting an ideal protection device.

Grid-Connected to/from Off-Grid Transference for Micro-Grid Inverters
Daniel Heredero-Peris, Cristian Chillon-Anton, Marc Pages-Gimenez, Gabriel Gross, Daniel Montesinos-Miracle, CITCEA-UPC, ES
This paper compares two methods for controlling the on-line transference from connected to stand-alone mode and viceversa in converters for micro-grids. The first proposes a method where the converter changes from CSI in grid-connected mode to VSI in off-grid. In the second method, the inverter always works as a non-ideal voltage source, acting as VSI, using droop control.

Development of a 15 MW Hardware in the Loop Electric Grid Test Facility
Thomas Salem, Curtiss Fox, Clemson University, USA
Clemson University is constructing a facility that combines a real-time power grid simulator system with a 15 MW power amplifier capable of arbitrary waveform generation in a physical system that has a reactive divider to emulate power line fault conditions on a 24 kV electrical grid. The facility is scheduled to be fully operational in late 2013 or early 2014 and promises to be a valuable asset to the global power community for years to come.

Application of Multi-Converter in the Peak Power Corrector
Nikolay Dyakin, Sergey Dyakin, Sergey Volksiy, Transconverter, RUS
At present, interest in the power electronics has increased due to the development of alternative sources of energy and energy efficiency systems: it is wind energy, solar energy. At the moment, there are the problems in the area of electric power industry associated with congestion of power grid. In this article it is proved by the calculations, the need for the application of Multi-Convertor in a device called a peak power corrector (PPC).

Efficiency and Power Quality of Multi-mode UPS
Lorenzo Giuntini, General Electric Consumer & Industrial, CH
Multi-mode UPS are a recent trend, where efficiency is maximized by selecting the UPS operating mode depending on the quality of the input utility. This paper discussed multi-mode operation, and particularly Advanced ECO Mode, evaluating the resulting output quality against specific application requirements. In this context, compatibility of such technology with various Power Quality standards is validated through experimental verification.

Total Power Consumption of Inverter Air Conditioner in Household Application
Ljupcho Arsov, Slobodan Mirchevski, University of Skopje, MK; Iljaz Iljazi, South East European University, MK
Inverter type air conditioner, as significant household consumer, additionally complicates situation as non linear, non constant load and source of harmonics. In household only active energy is paying. The treating of power is according DIN 40110. The measurements are realized by virtual instrument for power quality monitoring based on NI LabVIEW™ platform. The presented investigation shows that consumed non active power is not negligible and searching the ways for its reducing are imposed.

A Method to Measure the Network Harmonic Impedance
Sandro Günter, Friedrich W. Fuchs, Christian-Albrechts-University of Kiel, D; Hans-Jürgen Hinrichs, UAS Kiel, D
In this paper the principle problem of grid impedance measurement at harmonic frequencies will be described. For there is a high pollution of harmonic currents in the low voltage supply grid, it is difficult to measure the grid impedance at these frequencies. A method to measure the harmonic impedance using injection of harmonic currents with different phase angles will be described. Simulation results will be presented that show the suitability of this method.

SUMU – Integrated Monitoring System for Mixed Grid-Systems Analysis
Matthias Gorski, Alexander Laue, Carsten Heising, Avasition, D; Volker Staudt, Ruhr-University of Bochum, D
Various grid-systems characteristics can be found (e.g. DC, 16.7Hz, 50Hz). The appearing signal diversity is increased by shared overhead transmission lines due to the resulting relevant 'mixed' signals in case of fault-based grid-system interconnections. To realize a reliable monitoring and protection system, both signal components have to be identified clearly. The modular SUMU is presented applying a 'virtual PLL' concept realized on a FPGA- and uC-based hardware structure.

Software Tools and Applications

A New Analog Behavioral Power IGBT Device Spice Macro Model with Thermal and Self Heating effects
Daniela Cavallaro, Gaetano Bazzano, STMicroelectronics, I
Self-heating effects in IGBT have been incorporated into Spice through Sub-circuits including thermal model. It contains a dynamic link between electrical and thermal components which allows a good prediction of DC and AC variation due to temperature in the range of the component. It allows estimating the junction-temperature when the device works in the power application. An example of thermal transient simulation is presented showing the thermal effects in a typical circuit configuration.

Noval Approach for Real-time Simulation of Power Electronic Circuits Comprising Fast FPGA based Output Models
Axel Kiffe, Manuel Brose, Thomas Schulte, University of Applied Sciences Ostwestfalen-Lippe, D
Hardware-in-the-loop simulation of power electronic devices is growing in importance in diverse industrial fields. Anyway real-time capable models of power electronics are required.
In this contribution a novel approach is presented, which applies simplified output-models for significantly improving the feedback dynamics of a hardware-in-the-loop simulation of power electronic devices.

The Real-time Simulation of a Solar Power Conditioner Using the General Electrical Hardware Solver on an FPGA
Weihua Wang, Luc-André Grégoire, Andy Yen, Jean Bélanger, OPAL-RT Technologies, CA
This paper presents the real-time simulation of a solar power conditioner, which is achieved on an FPGA using the general electrical FPGA hardware solver (eHS). The eHS is developed to facilitate the implementation of FPGA-based models for power converters with complex topologies. The real-time simulation results of the OPAL-RT eHS solver are validated by comparing with the results produced by off-line simulation a time-step of 100 nanoseconds using the PLECS blockset.

Behavioral Modeling of Power Losses in FSBB Converters
Valérie Dupé, Bruno Jammes, Lionel Séguier, Corinne Alonso, LAAS-CNRS, F
This paper proposes a behavioral model of DC-DC converters losses dedicated to photovoltaic applications. The objective is to introduce accurate DC-DC converter's efficiency into long range system simulations. Our approach has been validated on a four switch buck boost converter (FSBB). Experimental power losses have been fitted with multivariable polynomial functions for the different operating modes of each cell of the converter. A VHDL-AMS model of each cell has been developed.

FPGA-Based Brushless Synchronous Generator Real-Time Emulator for Digital Controllers Testing
Lahoucine Idkhajine, Eric Monmasson, SATIE-UCP, F; Mohamed Dagbagi, I. Slama-Belkhodja, Tunis National School of Engineering, TN; Mathias Tientcheu-Yamdeu, Leroy Somer Emerson, F
The aim of this paper is to present a Field Programmable Gate Array (FPGA) based real-time emulator of a brushless synchronous generator. This emulator is intended for testing digital controllers in the context of Hardware In-the Loop validation. The developed FPGA-based emulator has been implemented and validated on the low-cost Xilinx Spartan-6 target. The obtained real time results are given and an evaluation of time/area performances is achieved.

Simulation Optimized Design for Vibration Resistant Power Module Package
Frank Sauerland, Indrajit Paul, Christian Steininger, Infineon Technologies, D
IGBT based power modules designed for usual industrial application cannot be transferred without changes to a Commercial, Agriculture and Construction Vehicles (CAV) applications because of their higher overall system requirements in terms of vibration and harshness. This paper describes the simulation flow to construct a more vibration resistant power module for a CAV application.

Modelling and Analysis of an Inductor – Piece System with Differentiated Domains of the Electromagnetic Fields in the Inductor
Mincho Simeonov, Hristo Ibrishimov, Prodan Prodanov, Technical University of Gabrovo, BG
The electromagnetic parameters of an inductor with differentiated domains of the electromagnetic field within it are calculated by means of the method proposed. The analysis is expanded by the modelling of processes using COMSOL Multiphysics 4.3.a. The results obtained confirm the correctness of the method developed, compared to the production and power indicators of the supply source in relation to power, current and frequency for the example taken from practice

A Fast Analytical Method to Predict DC Operating Point of DC-DC Switching Regulators in Discontinuous Conduction Mode
Giulia Di Capua, Nicola Femia, Walter Zamboni, University of Salerno, I
This paper presents a fast analytical method to predict the steady-state solution of whatever dc-dc converter in Discontinuous Conduction Mode without undergoing transient simulation. The method is based on the concept of average energy equivalence between Discontinuous and Continuous Conduction Mode for a dc-dc power converter operating at given input and output termination conditions. Thanks to energetic considerations the method provides analytical results which are in excellent agreement wit

Implementation of Combined-Hardware-in-the-Loop-System – Binarloop
Volker Staudt, Ruhr-University of Bochum, D; Matthias Thesseling, Matthias Gorski, Roman Bartelt, Carsten Heising, Avasition, D
In power-electronic development processes, safe test procedures are crucial: HIL verifies proper functionality of the Device under Test (DUT). Due to the digital realization of HIL, a non-negligible delay is introduced which drive cycle-time reductions – leading to expensive systems and numerical problems. Combined HIL is presented circumventing the challenge. The new methodology removes the limitations and improves the quality of results while at the same time reducing effort and costs.

Control-Unit Prototyping Using the VIAvento Code-Generation Framework
Carsten Heising, Christian Schilling, Martin Richter, Avasition, D
Control design for electric power converters involves the design and validation of numerical algorithms. In practice, software and hardware simulations do not use the same source code (e.g. C, VHDL). Within the scope of the environment VIAvento, an extensible code-generation framework has been developed aiming at assisting control-design assessment using a uniform programming language. The presented framework hides aspects like target specific memory management and run-time diagnostics.

Keynote: High-density Fast-transient Voltage Regulator Module
Speaker: Qiang Li, Virginia Polytechnic Institute and State University, USA

Chip Interfacing Technologies

Solder TIMs (Thermal Interface Materials) for Superior Thermal Management in Power Electronics
Karthik Vijay, Indium Corporation, UK
This paper discusses In-contained solder TIMs, with an altered surface for reduced thermal interface resistance, developed specifically for high-power applications. With higher heat dissipation needs, solder TIMs are better suited than thermal grease for the following reasons: (a) Higher bulk conductivity than grease; (b) No pump out or bakeout as grease; (c) Softness and mallelability of In fills gaps better especially over time this further reducing interface resistance.

Investigation of Silicone Soft Gels at Low Temperatures
Heiko Knoll, IXYS Semiconductor, D
Unfilled silicone gels are often used for the internal encapsulation of power electronic modules. Standard silicone gels are most specified in the temperature range of -40°C...150°C which covers the typical storage and application temperatures. In this work a failure mode (wire bond tensile break) for a typical power module with standard silicone gel under thermal cycling between –65°C and 150°C is described.
In addition a simple and robust method for silicone gel hardness measurement is presented and the hardness behavior for a standard gel and three low temperature gels at different temperatures is compared.

Study on Aluminum Reconstruction and Bond Wire Lift-off Effects on Current Distribution in Power Semiconductor Dies
Stéphane Lefebvre, Tien Anh Nguyen, Denis Labrousse, SATIE, F; Pierre-Yves Joubert, University of Paris-Sud, F; Serge Bontemps, Microsemi Power Module Products, F
The ageing of the metallization layer on dies of power semiconductor modules results in the redistribution of the current lines in the elementary cells with a risk of failure when local current density or local temperature reach a critical value. Similar effects can be observed after bond wires lift-off due to current redistribution in the die. The local distribution of the current is obtained from a map of the potential of the source metallization. Results help to understand origin of failure.

Transient Liquid Phase Soldering – An Emerging Joining Technique for Power Electronic Devices
Christian Ehrhardt, Klaus-Dieter Lang, Technical University of Berlin, D; Matthias Hutter, Hermann Oppermann, Fraunhofer IZM, D
The Transient Liquid Phase Soldering (TLPS) is a new lead-free joining technology for power electronic modules in high temperature applications. This alternative solder technique is based on a phase transformation using a low and high melding powder.

Silver Sintering as Lead Free Die Attach Technology in Discrete Power Packages
Thomas Krebs, Wolfgang Schmitt, Heraeus Materials Technology, D; Gretchen Adema, Alberto Calicdan, International Rectifier, USA
In this paper, the usability of sinter pastes as lead free die attach material will be shown for selected packages. Properties and application processes of the novel mAgic silver sinter paste for die attach on lead frame will be presented. In addition, advantages, limitation and reliability results of sinter paste will be discussed.

Power Semiconductor Switches II

Large-Area 6.5 kV Fast Recovery Diode with Cathode Shorts for Very High Current Handling Capability
Jan Vobecky, ABB Switzerland, CH; Libor Pina, ABB, CZ
Large-area 6.5 kV P-i-N discrete diodes with cathode shorts can achieve a better technology curve between the static and dynamic losses compared to existing designs while conserving the reverse recovery softness. The new design can reduce around 10% of the original thickness, which translates to 40% lower Erec for a diode with Vf=3V @ If=2.5kA @ 140degC. For the same device thickness, the Erec is reduced by 9%.

Optimization of High Voltage IGCTs towards 1V On-State Losses
Munaf Rahimo, Martin Arnold, Umamaheswara Vemulapati, Thomas Stiasny, ABB Switzerland, CH
Nominated for the Best Paper Award
The IGCT is a device which will lend itself well to lower conduction losses in modern applications due to its inherent low conduction loss thyristor properties on the one hand, and the hard switched functionality on the other. Therefore, in this paper, we demonstrate by simulation and experiment the feasibility of designing through “anode engineering” a wide range of HV-IGCTs with very low on-state losses approaching the 1V value, which many applications strive for today.

First Generation of 650V Super Junction Devices with RDS(on)*A Values Below 1 Ω*mm2 – Best Efficiency that Keeps the Ease-of-use and Enables Higher Power Ratings and Frequencies
Enrique Vecino, Infineon Technologies, D; Franz Stückler, M. Pippan, Infineon Technologies, A; J. Hancock, Infineon Technologies, USA
In this paper the latest high-voltage superjunction MOSFET of Infineon Technologies, CoolMOS™ C7, is described. Typical RDS(on) values below 1 Ω*mm2 have been achieved for the first time and the switching FOMs have been optimized to keep a good ease-of-use while, at the same time, the best efficiency for hard switching applications can be achieved when compared to previous generations and main competitors. The presented results confirm C7 as an enabler of higher frequencies and/or power ratings.

The New Evolution with Bottom-Source Power MOSFET for Power Conversion
Roland Weber, Alpha and Omega Semiconductor, D; Yalcin Bulut, Alex Niu, Daniel Ng, Sabin Lupan, Zach Zhang, Alpha and Omega Semiconductor, USA
This paper will illustrate the benefits of new power semiconductors which utilize a source down technology for board mounting in power applications such as DC/DC converters. This new packaging technology allows for top and bottom side cooling enabling higher current densities in demanding applications such as servers, power supplies, and other high demanding power conversion applications.

Performance Improvement of a CoolMOS™ C7 650V Switch in a Kelvin Source Configuration
Franz Stückler, Bernhard Zojer, Matteo-Alessandro Kutschak, Roberto Quaglino, Infineon Technologies, A; Enrique Vecino, Matthias Benda, Heiko Rettinger, Infineon Technologies, D
In todays power applications the effects of the parasitic source inductance often limits overall system performance. An effective measure to overcome this problem is to provide a Kelvin connection to the source of the switch as a reference potential for the gate driver, thereby eliminating the effect of voltage drops. The achievable efficiency improvement is demonstrated for Infineon’s latest generation of power transistors by both simulations and measurements. As a drawback the gate driving circuitry has to deal with large voltage spikes. Thus a dedicated gate driver IC, that isolates output from input by means of an integrated coreless transformer, has been developed.

DC/DC Converter

Controlled-Bus Architecture with Voltage Equalization: a System Approach to Higher Efficiency in Low Voltage DC Distribution
Maurizio Salato, Eduardo Oliveira, Vicor Corporation, USA
Telecommunications “Central Offices” have been historically powered by a wide range 48V distribution, with battery-backup being the main driver behind this choice. The relative simplicity of this scheme implies that converters need to accommodate for wide input voltage range, which implies lower distribution and power conversion efficiency. This paper describes an architectural approach which not only increases the overall power system efficiency but also reduces the losses on load motherboards.

Isolated High Voltage DC/DC Converter for Auxiliary Power Supply in Commercial Vehicles
Bernd Seliger, Jordan Popov, Bernd Eckardt, Martin März, Fraunhofer IISB, D
This paper presents an isolated 5 kW DC/DC converter with 2-phases and input voltages up to 800 V. The serial connected phases on primary side allow the use of semiconductors with only 600 V blocking voltage instead of the normally necessary 1200 V. The considerably better electrical properties of 600 V devices reduce losses and a power density of 5 kW/l could be achieved. On the other hand the control requirements increase. The implementation of the digital control is explained in detail.

Switching Behavior of IGBTs in Phase Shift Full Bridge ZVT DC/DC Converter
Sandra Zeljkovic, Thomas Reiter, Infineon Technologies, D; Dieter Gerling, University of the Federal Armed Forces Munich, D
Effect of additional components for efficiency improvements (external resonant inductors and capacitive snubbers typically used with MOSFET switches) on switching losses of IGBTs and overall converter efficiency in ZVT phase shift full bridge HV to LV DC/DC converter for hybrid and electric vehicles is discussed based on experimental results from a prototype converter.

Bi-directional DC/DC Converter for Battery Management with New High Bandwidth Bi directional Digital Feedback Loop
Bernhard Strzalkowski, Analog Devices, D
Bi-directional isolated DC/DC power converters need two feedback signals to control bi-directional power flow. One feedback signals has to be transfer to the controller over isolation barrier. In the new method, the isolated feedback signal doesn't need to be transfer over the barrier. The controller works in bi-directional close loop mode. In the forward mode (voltage-fed), the converter works by using existing compensator. In backward mode (current-fed), appropriate PWM mode works well.

Comparison of Bidirectional Medium-Voltage DC-DC Converters for Energy Harvesting Using Dielectric Elastomers
Todor Todorcevic, Pavol Bauer, Jan Abraham Ferreira, Delft University of Technology, NL
This paper presents a comparison of different medium-voltage bidirectional DC-DC converter topologies for energy harvesting using dielectric elastomer (DE) wave generators. The compared topologies are capable of accepting the 10-kV voltage input from the DE, while the DE is charged and discharged to yield maximum energy. Comparison framework is created in order to find the most suitable converter topology for this application and as a result cascaded multilevel is chosen for future development.

DC/AC Converter

Three-level or Two-Level Two-cell Interleaved DC-AC Converter: What is a Right Choice?
Petar Grbovic, Huawei Technologies, D
The objective of this work is to systematically compare three-level with two-level two-cell interleaved dc-ac converter and determine what topology is better for a given application requirements. Relevant factors such as cost of silicon per kVA, silicon efficiency versus power capability and switching frequency, size, cost and losses of the dc bus capacitors, and filter inductors cost, size and losses are compared.

The optimum converter topology for high speed motor drives with varying DC-link voltage under different cooling conditions
Roman Horff, Mark-M. Bakran, University of Bayreuth, D
Nominated for the Young Engineer Award
This paper describes a converter topology comparison for high speed three-phase motor drives with varying DC-link voltage (e.g. battery storage system).
Forced air cooling and water cooling are assumed and their influence on the choice of the optimum converter topology and the maximum converter performance is evaluated. The Total Harmonic Distortion (THD) and output power per silicon area is introduced as figure of merit.

Novel DC-AC Converter Topology for Multilevel Battery Energy Storage Systems
Mario Gommeringer, Karlsruhe Institute of Technology, D
Nominated for the Young Engineer Award
A novel DC-AC converter circuit, especially for the usage in multilevel battery energy storage systems is presented. The battery currents of standard cascaded H-bridge converters contain AC components. These AC components can be reduced by additional DC-DC converters. The presented circuit causes less semicondutor losses and requires smaller inductors than standard DC-DC converters connected to H-bridges.

Design of a Soft-switching Inverter Operating in the MHz-range Based on SiC MOSFETs
Karsten Haehre, Rainer Kling, Wolfgang Heering, Karlsruhe Institute of Technology, D
Nominated for the Young Engineer Award
Silicon Carbide (SiC) semiconductor devices offer low conduction and switching losses at voltages higher than one kV. Compared to Silicon (Si) IGBTs and MOSFETs, SiC devices feature these advantages at much smaller chip sizes. For instance, SiC devices exhibit smaller parasitic capacitance values than Si, allowing zero voltage switching at smaller load currents and higher frequencies due to shorter commutation dead times. This work presents the design, the simulation and the implementation of a soft-switching half-bridge inverter, op-erating in the MHz-range based on SiC MOSFETs (Cree Inc., USA). Targeted application ar-eas are e.g. lighting electronics, inductive heating amplifiers or wireless power transfer sys-tems, as well as high power density dc-dc converters.

Special Session “Power GaN for Highly Efficient Converters”

GaN on Silicon Technology, Devices and Applications
Alex Lidow, Johan Strydom, David Reusch, Michael de Rooij, Efficient Power Conversion, USA
Much progress has been made improving gallium nitride transistor performance and reliability recently. As a result, several new power management applications have emerged. Two of these applications, RF Envelope Tracking and high frequency Wireless Power Transfer, exceed the fundamental capability for the aging power MOSFET. These and several other eGaN® FET applications will be discussed, as will the latest in device technology and future direction for GaN discrete and integrated circuits.

Latest High Voltage GaN Devices for Inverters
Umesh Mishra, Yifeng Wu, Transphorm, USA
Short description for official online program (subject to committee approval): During the past decade improvements in semiconductors have lead the way to more efficient systems, but further advances in silicon devices have come close to a wall limited by inherent semiconductor properties. Luckily devices based on GaN have emerged and now matured enough to demonstrate higher efficiency in inverter circuits for both solar and motor drive systems. This presentation covers the rapid progress made

Development of GaN Switches for Efficient Converters
Girvan Patterson, GaN Systems, CA
GaN transistor switching speeds of a few nanoseconds and two orders of magnitude improvement in specific on-resistance over silicon devices improves volumetric and conversion efficiency in any power systems and has particular relevance to solar and wind inverters. GaN Systems novel switch topology maximizes these advantages whilst reducing cost of manufacture. To derive the maximum benefit from these devices requires new circuit design and construction techniques. GaN Systems is investing heavil

The Status of 600 V GaN on Si based Power Device Development at International Rectifier
Michael Briere, ACOO Enterprises LLC for IR, USA
Experimental results for the use of GaN-based power devices in highly efficient high frequency power circuits such as ac-dc power supplies, dc-ac inverters and dc-dc boost and buck converters are presented. The current status of the development and current performance of the required 600 V rated GaN on Si based devices at IR are presented. Results of long term reliability studies of more than 2500 hrs will be presented as well as results for device robustness in application conditions.

Special Session “Solar Power II”

New Topology for Energy Storage in PV-Inverter
W.-Toke Franke, Danfoss Solar Inverters, DK
Nominated for the Young Engineer Award
In this paper a new topology to store energy for PV-applications is proposed. Therefore the existing solutions are analyzed and compared to this topology. It is shown that the new topology is less complex and much more efficient than the conventional variants.

Dynamic MPP Performance of PV Inverter Systems
Georg Lauss, Roland Bründlinger, Benoît Bletterie, Austrian Institute of Technology, A
This work is focusing on an evaluation of the MPP efficiency under static, dynamic and nonlinear conditions for diverse classes of PV inverters operating as small scale generation units.

Simulation of Utility-Scale PV Power Plants
Stefan Kempen, Hendrik Noack, AEG Power Solutions, D; Sebastian Klötzer, Klaus Hoffmann, Helmut Schmidt University of Hamburg, D
Utility scale photovoltaic (PV) power plants can produce technical issues occurring at the system level although any of the required tests were passed on the individual inverter level. To limit the risk of running into unexpected technical issues at the system level during com-missioning phase, innovative simulation methods and tools can be applied. This paper will provide an overview on how PV power plant specific issues can be identified in the early phase of project planning by use of different simulation tools and methods. Basically, offline simulation and real-time simulation will be addressed.

Algorithms and Devices for the Dynamical Reconfiguration of PV Arrays
Patrizio Manganiello, Massimo Vitelli, Second University of Napoli, I; Giovanni Spagnuolo, Pietro Luigi Carotenuto, Giovanni Petrone, University of Salerno, I; Salvatore Curcio, Bitron, I
Shadowing, manufacturing tolerances and parametric drifts introduce mismatching effects in photovoltaic (PV) arrays. The consequent power drop can be faced by using power optimizers, which are module dedicated dc/dc converters, or micro inverters. A recent alternative is the dynamical re-configuration of the PV array by means of active switches. An overview of the main re-configuration algorithms and devices presented in literature and available on the market is given in this paper.

Advanced EMC/PFC System Design

Effective Common Mode Noise Filtering by Means of Passive Cancellation: Some Important Aspects
Martin Schmidt, Jürgen Stahl, Manfred Albach, University of Erlangen-Nuremberg, D
Passive cancellation of common mode (cm) noise is a very promising alternative to conservative cm filtering. A thorough analysis of parasitic effects as well as the effects of a finite differential mode (dm) filter shows that a significant reduction of cm noise is achievable. However, the asymmetries in the boost converter and the parasitic equivalent series inductance (ESL) in the dm filter generate a noteworthy dm noise in the frequency range above 10MHz. A detailed investigation is essential.

A Simplification Method of a Modeling of Stray Magnetic Couplings in EMC Filters
Takashi Masuzawa, Denso Corporation, J; Eckart Hoene, Fraunhofer IZM, D
It is well known that a filter performance in power electronics is strongly influenced by magnetic couplings between the components. Hence several methods were proposed to predict these influences. Although a precise simulation can be realized by those methods, it is not practical to consider the all couplings in a product due to the high complexity.
This paper proposes a simplification method that identifies the most significant influences and reduces the investigation effort remarkably.

Digitally Controlled Bridgeless PFC with Embedded AC Power Metering
Kevin Huang, Botao Miao, Gabriele Bernardinis, Navdeep Dhanjal, Analog Devices, USA
This paper discusses an implementation of bridgeless PFC with the
finite state machine-based digital PFC controller embedded with AC power metering for universal line voltage applications. This bridgeless PFC solution presents several advantages such as high AC power metering accuracy, high power factor, low THD, fast transient response, low bias power consumption and low cost.

Control of a Discontinuous-Conduction-Mode ZVS Buck-Boost Topology for MicroprocessorCore Power
Eduardo Oliveira, Adnan Zolj, Maurizio Salato, Paul Yeaman, Xiaoyan Yu, Vicor Corporation, USA

Power Cycling Improvements

Lifetime Modelling of IGBT Modules Subjected to Power Cycling Tests
Yangang Wang, Steve Jones, Dinesh Chamund, Gary Liu, Dynex Semiconductor, UK
It is essential to estimate power IGBT module lifetime for both manufacturers and customers, which can be achieved by lifetime models and application profiles. In this work, we present a different methodology for modelling lifetime of IGBT module. The development is based on thermo-mechanical principle and is applicable to wire bonds and solder interfaces. By using the combination of models for wire bonds and solders, and the mission profile, the lifetime of an IGBT module can be predicted.

A New Lifetime Model for Advanced Power Modules with Sintered Chips and Optimized Al Wire Bonds
Uwe Scheuermann, Ralf Schmidt, SEMIKRON Elektronik, D
Nominated for the Best Paper Award
The prediction of power module lifetime is an aspect of high interest for power electronic system design. The demand for a significant increase in lifetime has led to an advanced power module architecture, where the base plate is eliminated, the die attach solder layer is replaced by Ag diffusion sintering technology and Al wire bond geometry is optimized. After years of testing, we can now present a new lifetime model for this advanced module design.

Statistical Analysis of Power Cycling Data
Aaron Hutzler, Andreas Schletz, Fraunhofer IISB, D
To assess the lifetime of a power electronic assembly power cycling is a common test method. A major problem of the power cycling test data analysis is the difference in test conditions between the single devices (different temperature swing), which means that the samples have to be divided into groups of same conditions. In this paper an analysis with statistical software is shown and solutions for the named problem is achieved.

Application Technologies of Direct Cooling IGBT Module for Electric and Hybrid Vehicles
Shinichiro Adachi, Akihiro Okdaka, Fumio Nagaune, Akio Toba, Akira Nishiura, Fuji Electric, J; Peter Dietrich, Fuji Electric, D
Application technologies which are the design of liquid cooling jacket for the direct cooling IGBT module and estimation of power cycling life time is very important to bring out the IGBT module performance and high reliability in automotive inverter system.we studied on liquid cooling jacket structure and estimation of IGBT module life time. The liquid cooling jacket structure has been optimized and it is proved that the power cycling life time of the IGBT module is enough for automotive.