Innovationen und Trends in der Leistungselektronik

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Outline

Power Electronics Applications

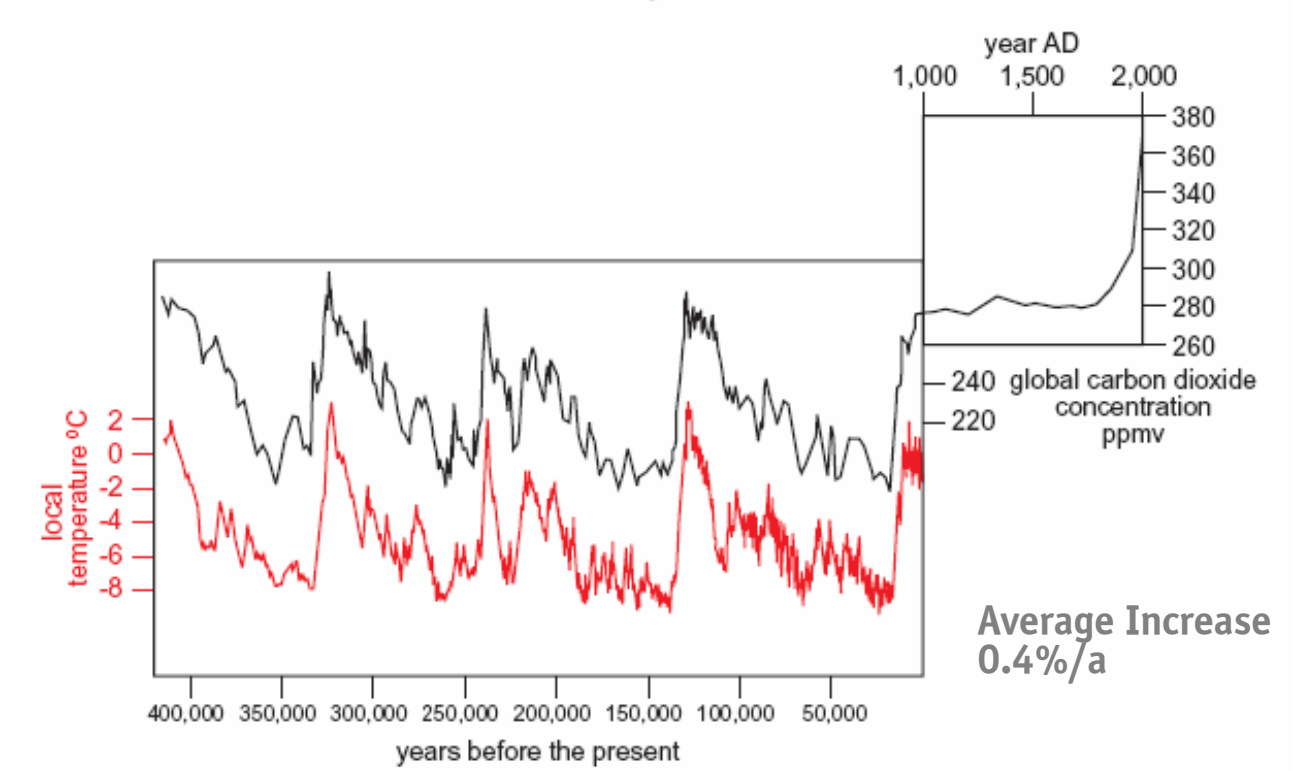
- Voltage Regulator Module
- IT Distributed Power Supply
- Hybrid Vehicle
- More Electric Aircraft
- Drive Systems
- Distributed Generation

Power Semiconductor Development

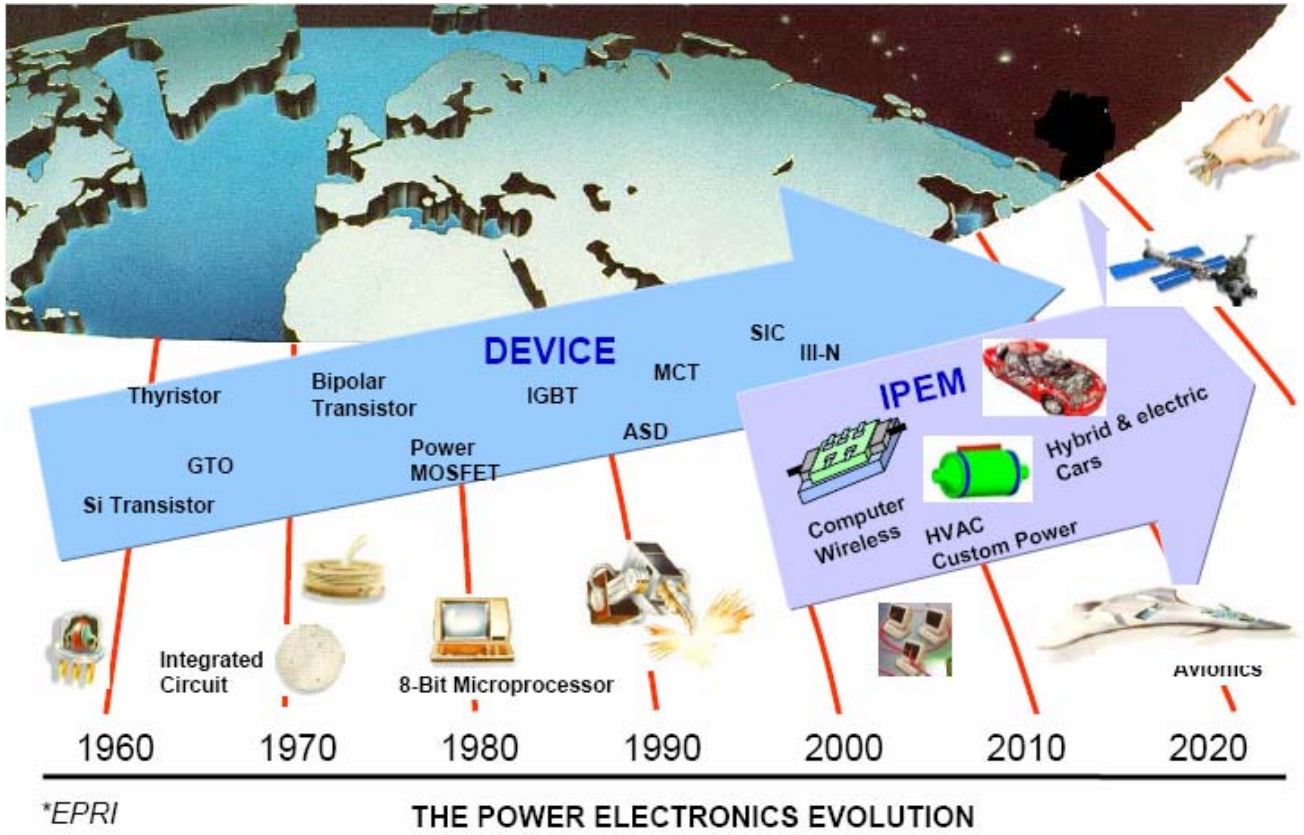
Power Electronics Research Centers

Carbon Dioxide Concentration and Temperature

Evidence from Ice Cores



Power Electronics Evolution

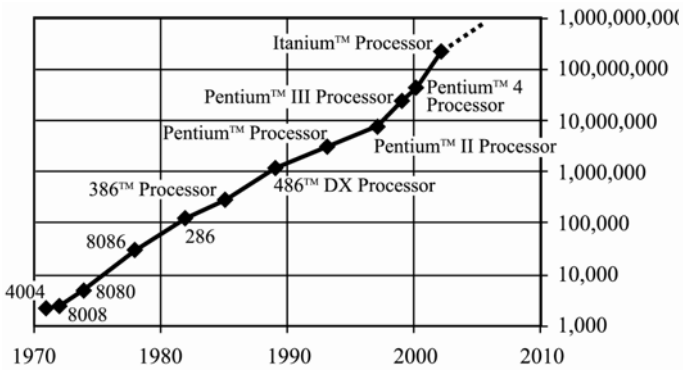


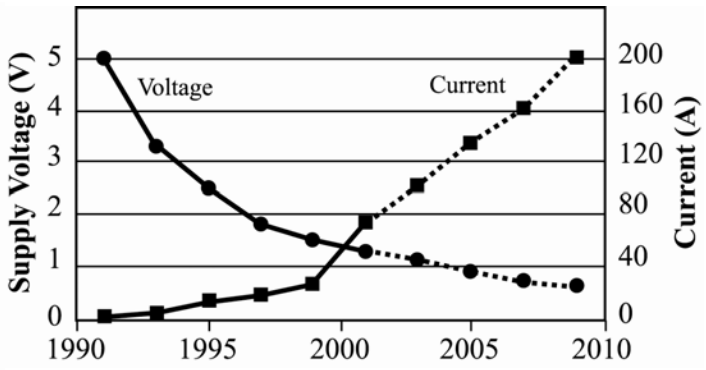
IT Distributed Power Supply

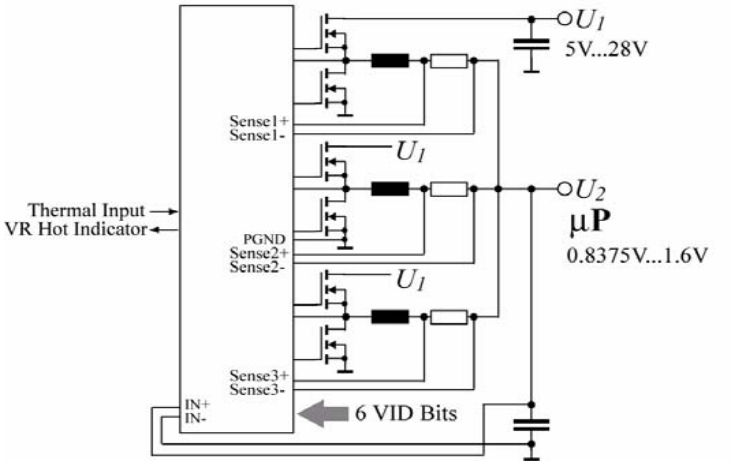
Server-Farm
450 MW/1.5kW/m^2
99.9999%/<30s/a
$1.0 Mio./shutdown

US 15% Digital Economy Electricity Consumption

Voltage Regulator Module



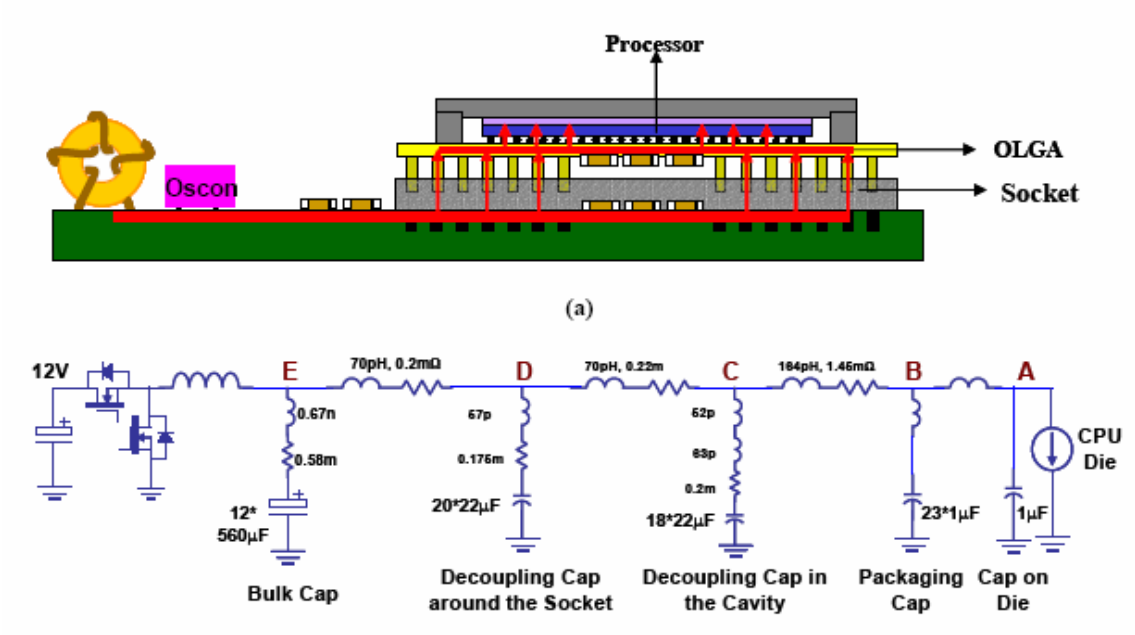




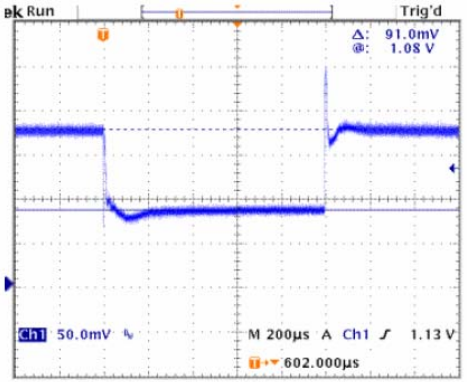
Moore´s Law will Prevail for the Next Decade
1 Billion Transistors
15 GHz by 2010
0.8V / 200A
250A/ns @ 1% Supply Voltage Tolerance

Power and Thermal Limitations
→ Power Wall

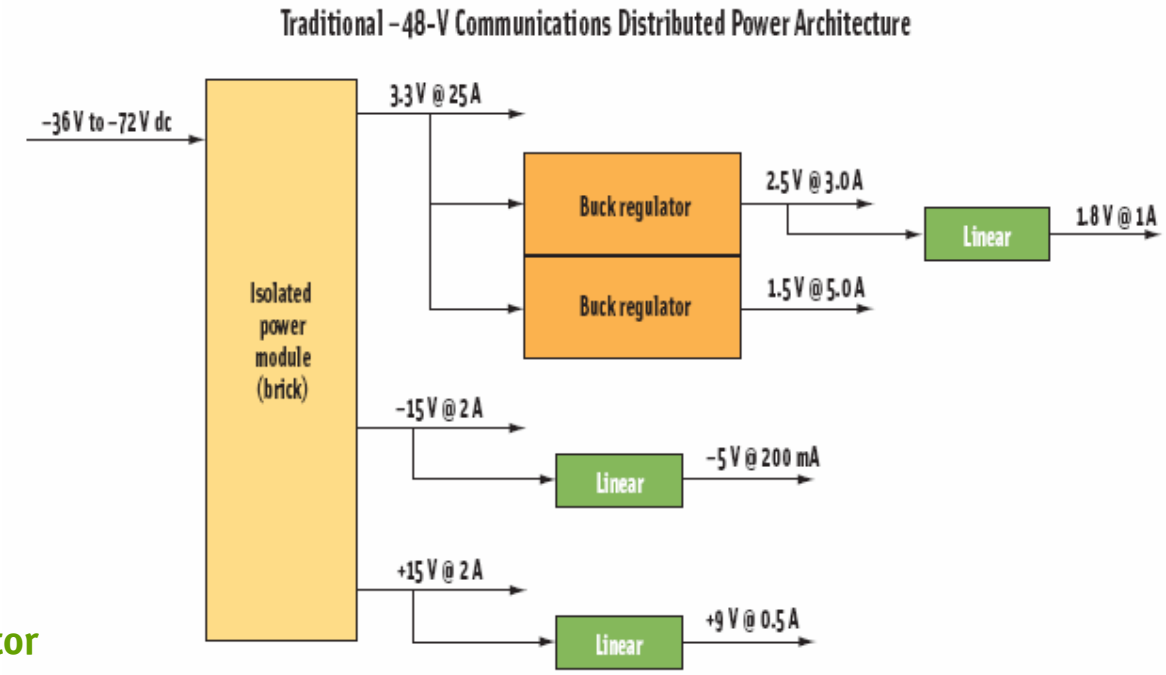
Voltage Regulator Module



Dynamic Behavior

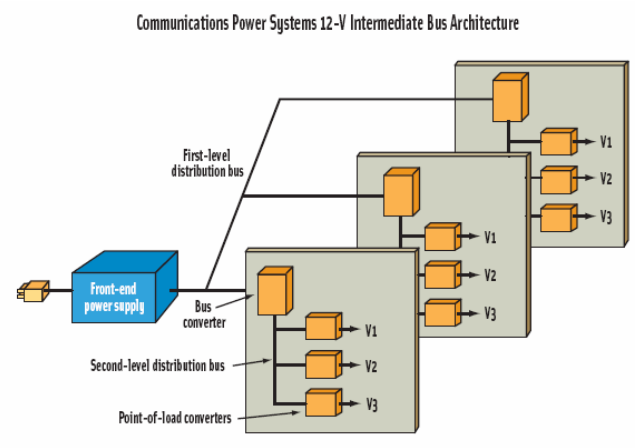


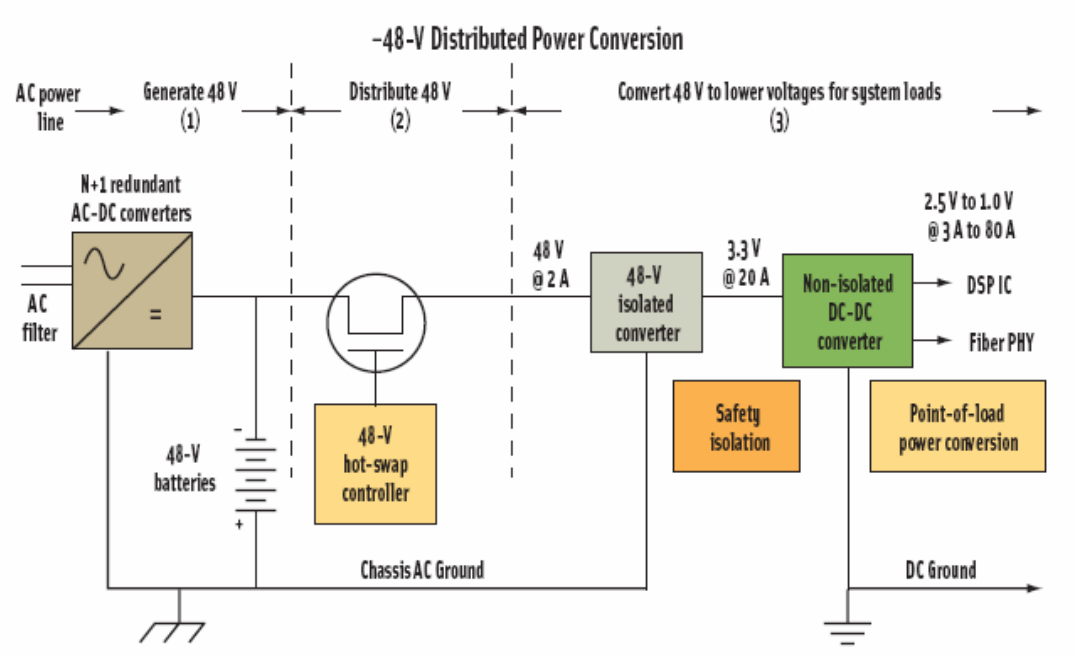
Traditional IT Power System Architecture



Linear Post Regulator

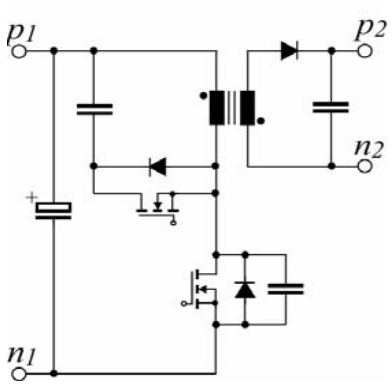
Intermediate Bus Architecture

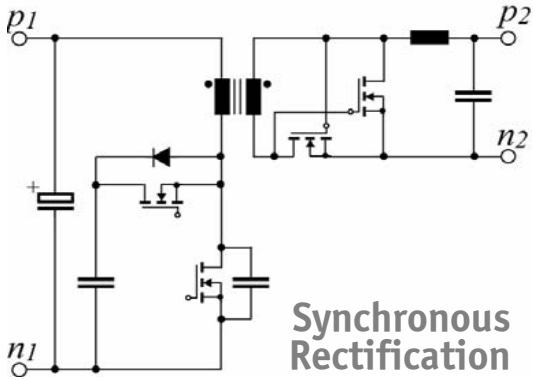




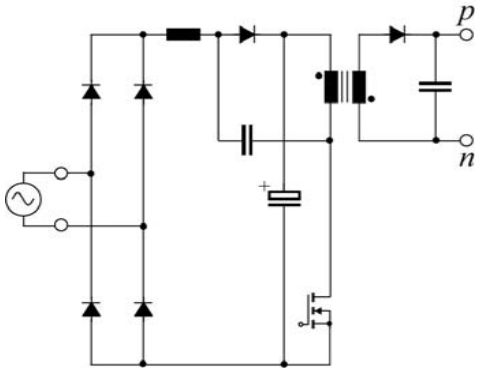
Intermediate Bus Architecture

Active Clamp Flyback and Forward Converter





Synchronous Rectification

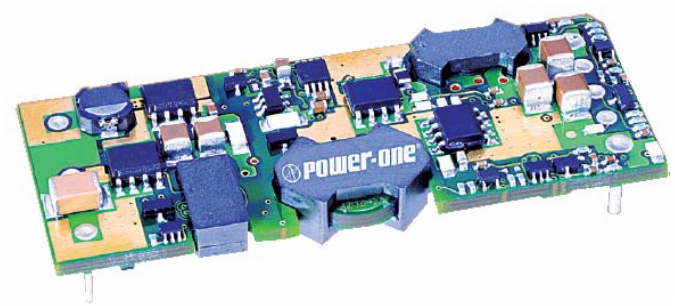


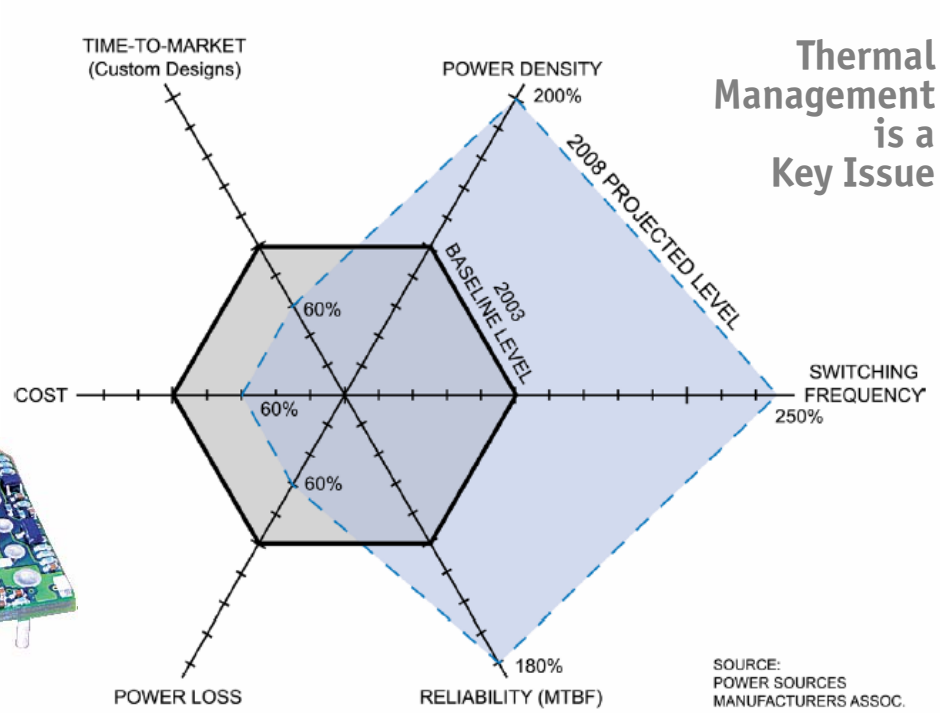
-48V

Single-Stage Power Factor Correction

DC/DC Converter Development Route

2003 - 2008

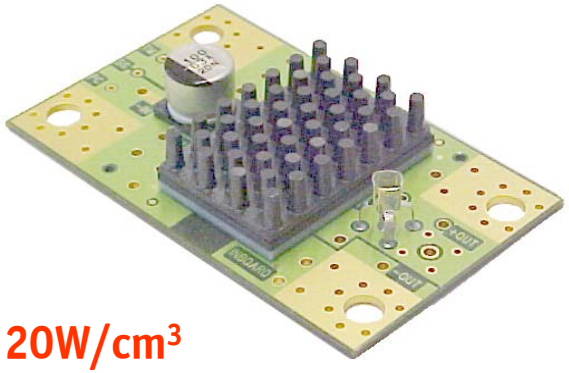




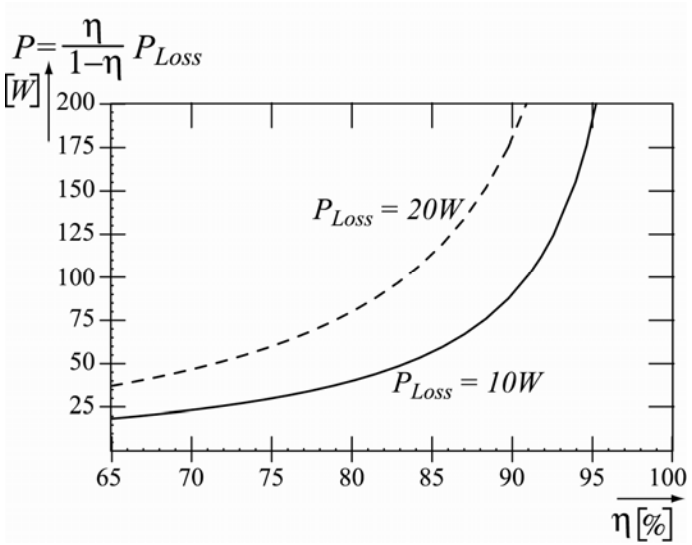
Thermal Management is a Key Issue

DC/DC Bus Converter Module

48V / 12V isolated
200W cont. Output
>96% Efficiency
3.5MHz (eff.)
BGA Surface Mounting

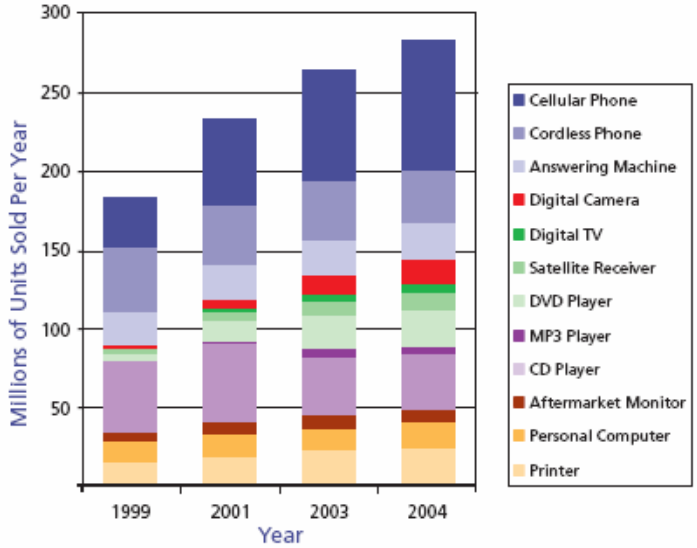


20W/cm³

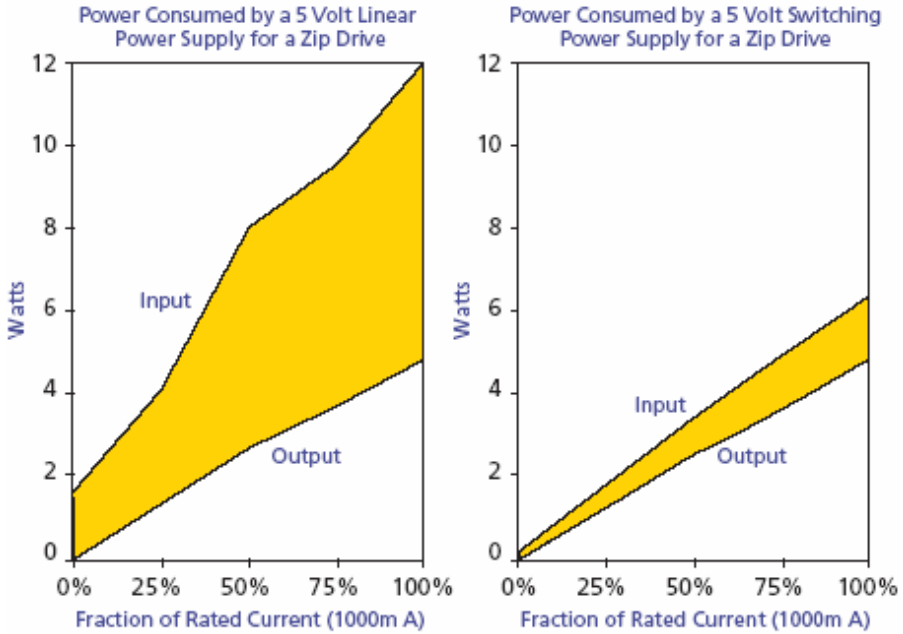


Power Supply Energy Efficiency

10 Billion Power Supplies in Use Woldwide
10% of US Electricity Use
30...60% Efficient

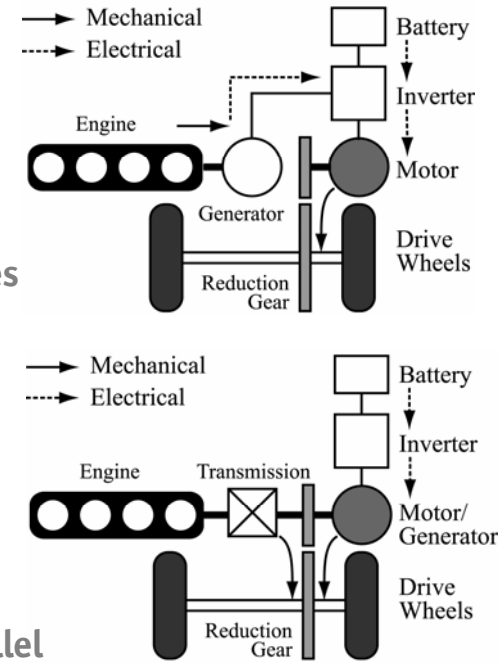


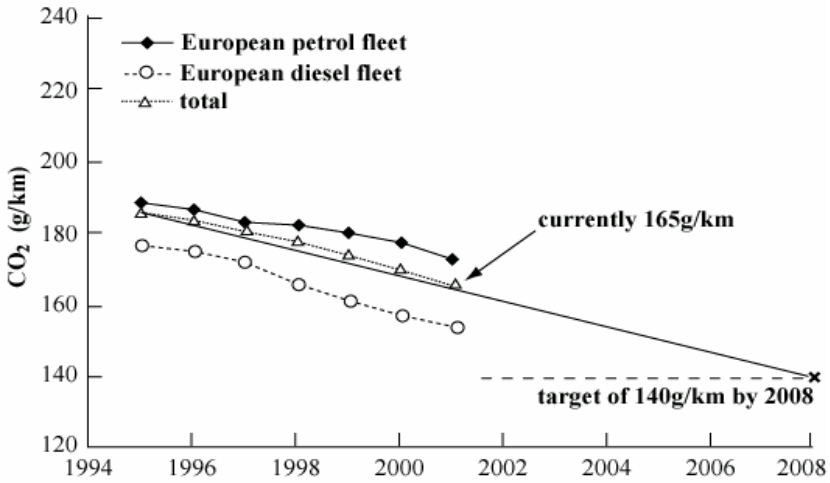
U.S. sales of these power supply-containing products are expected to rise 55% between 1999 and 2004. Source: Consumer Electronics Association



The shaded areas represent the net power consumption of each power supply – the amount of ac power input that is converted to heat instead of becoming useful dc power output. Both units are designed to produce a similar amount of dc output power across a range of loading conditions. But at 100% load, the linear design draws nearly twice the ac power of the switching design (12 watts vs. 6.3 watts). At 0% load, it draws more than 8 times the ac power (1.7 watts vs. 0.2 watts).

Hybrid Car

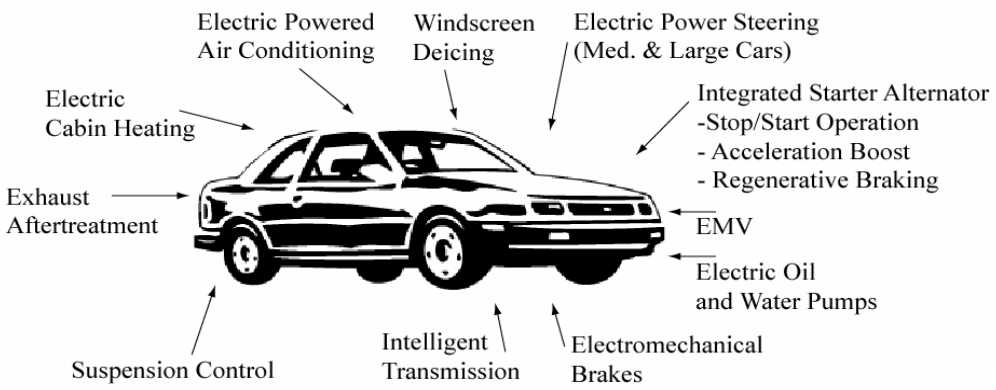

Mechanical
Electrical
Battery
Inverter
Engine
Motor
Generator
Drive Wheels
Reduction Gear
Series
Mechanical
Electrical
Battery
Inverter
Engine
Transmission
Motor/ Generator
Drive Wheels
Reduction Gear
Parallel

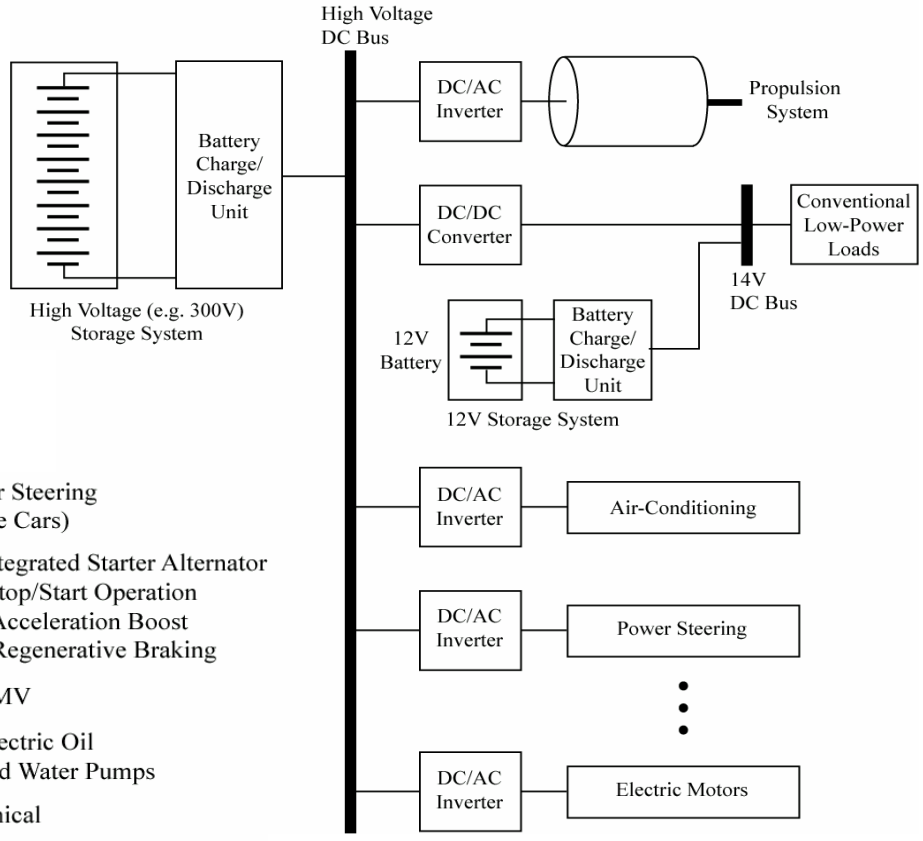

European petrol fleet
European diesel fleet
total
currently 165g/km
target of 140g/km by 2008
CO_2 (g/km)
240
220
200
180
160
140
120
1994
1996
1998
2000
2002
2004
2006
2008

Hybrid Car

Power System Architecture

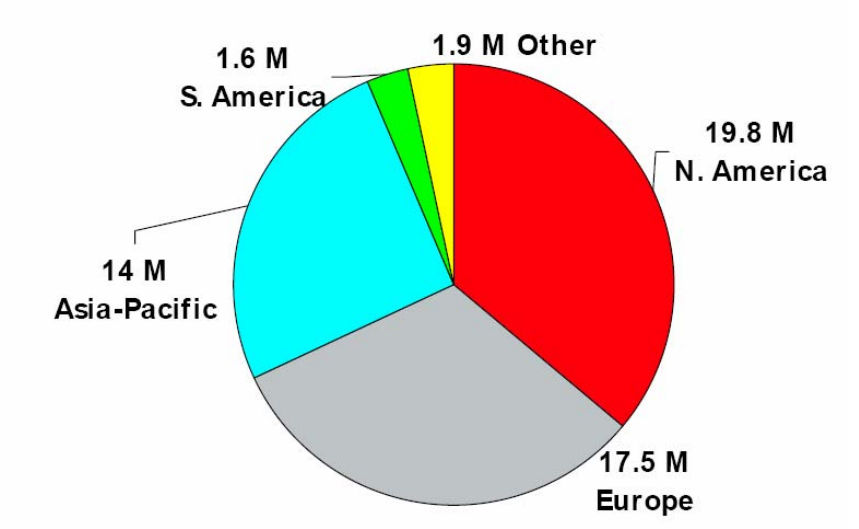
300...500V High Voltage DC Bus
14V Battery



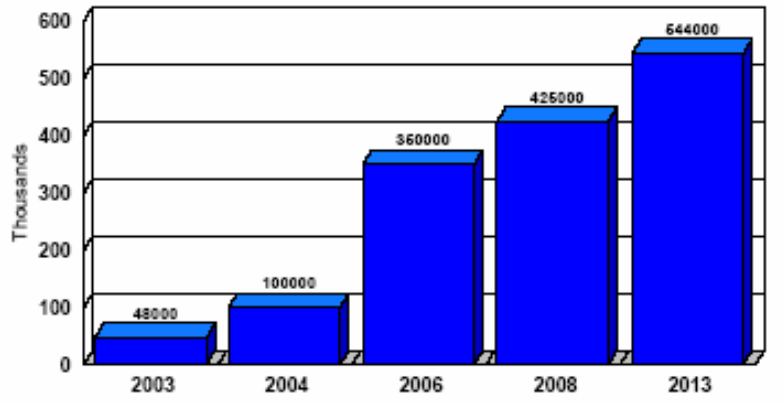


Hybrid Car Share Forecast

Annual World-Wide Car Manufacturing

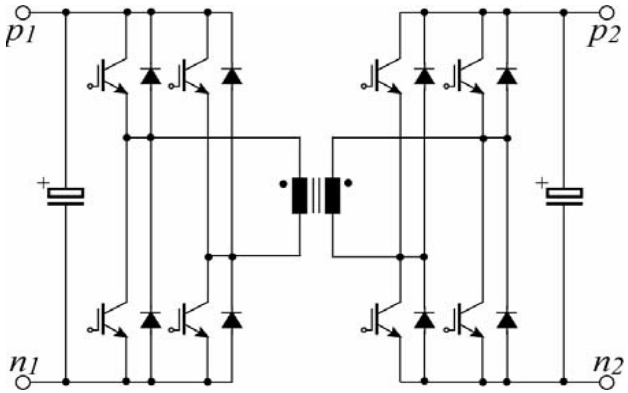


Forecast of Hybrid Vehicle in US

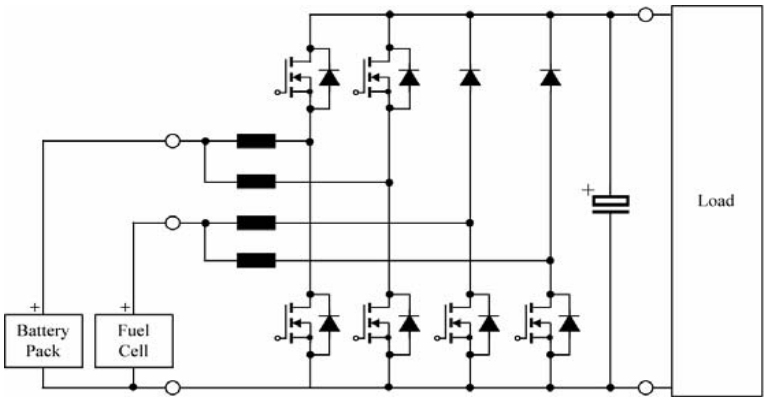


Hybrid Car

Bidirectional DC/DC Converter Topologies



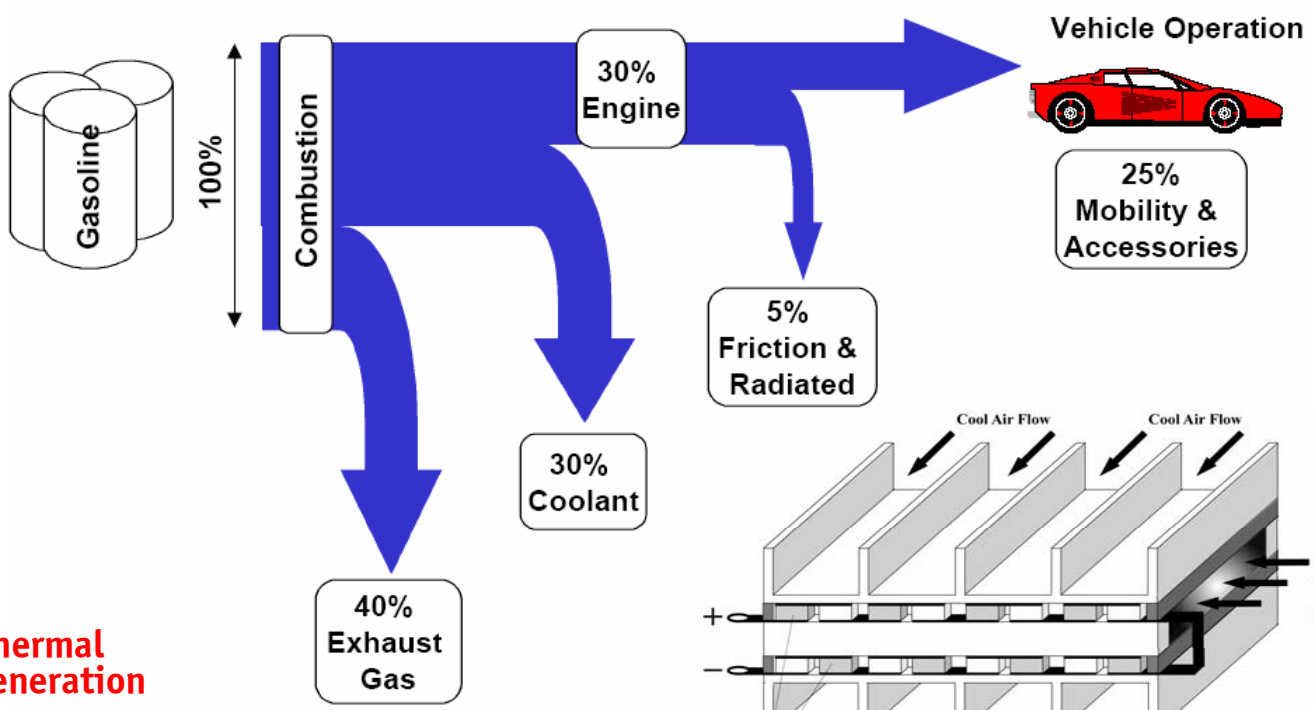
Isolated



Non-Isolated
Bidirectional / Unidirectional

More Electric Car

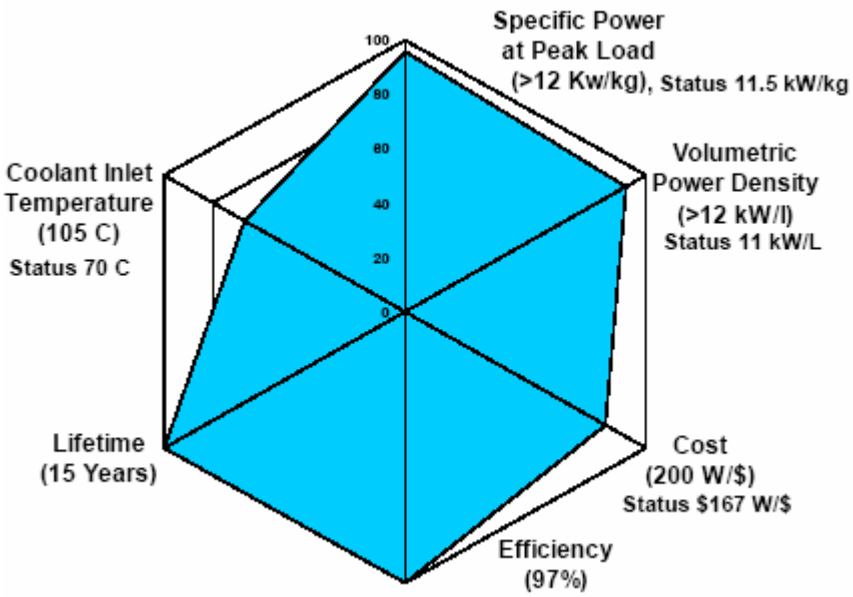
Waste Heat Recovery



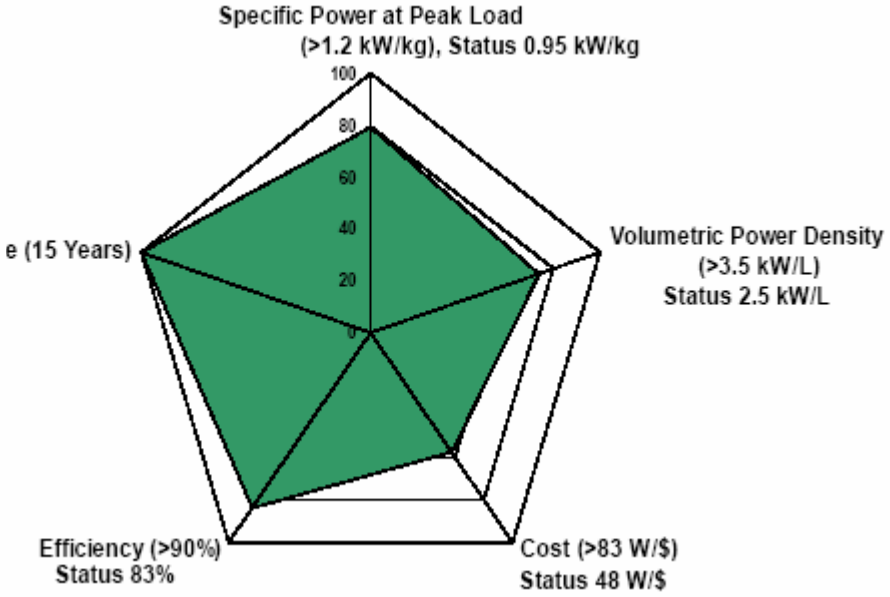
Electro-Thermal Energy Generation

More Electric Car

Technology Gaps



Power Electronics



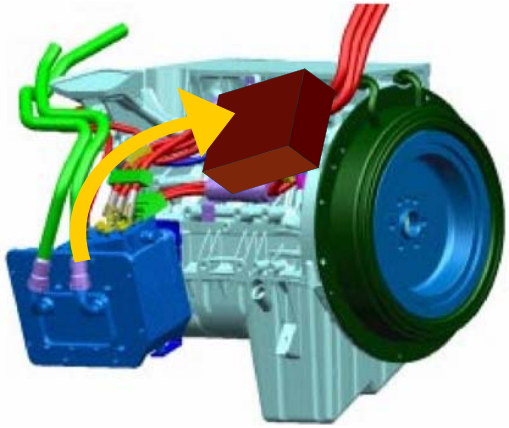
Propulsion System

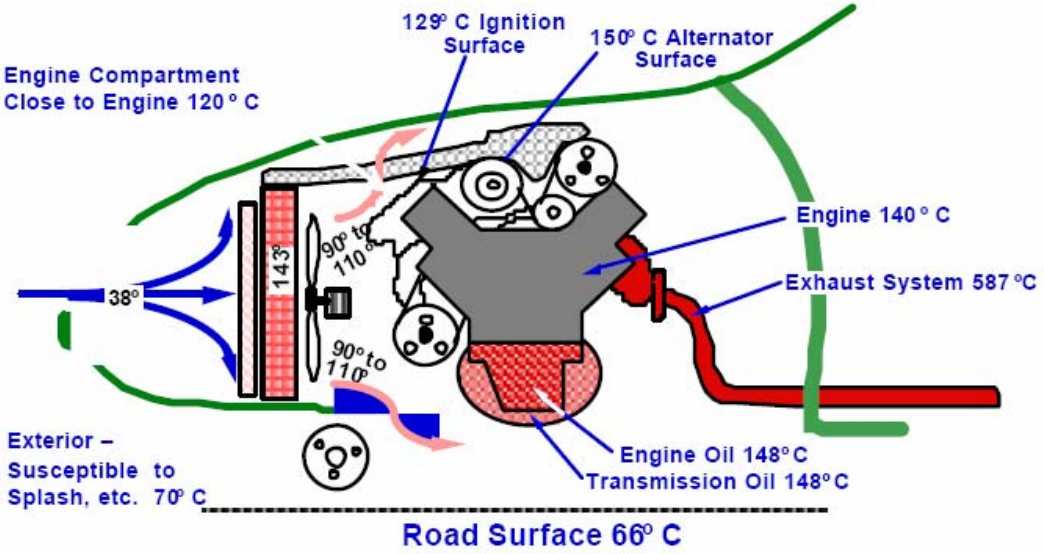
More Electric Car

Power Electronics Mounted to ICE 105°C

Increasing Ambient/Junction Temperature and Simultaneously Increasing Reliability Requirements

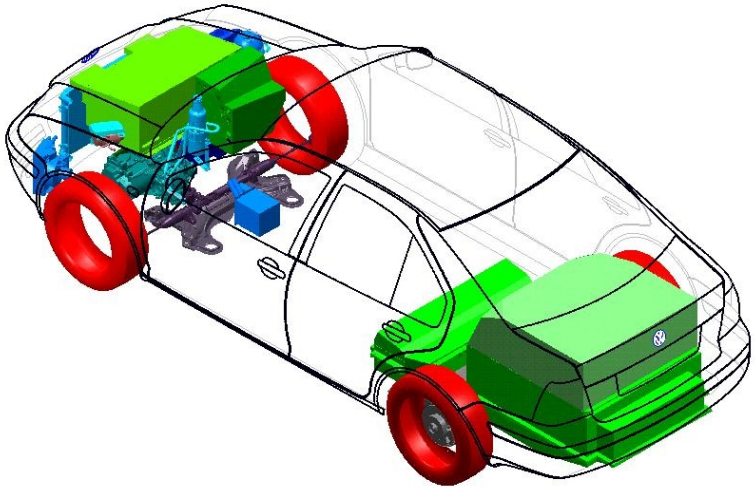
Packaging Technology with Matched CTEs

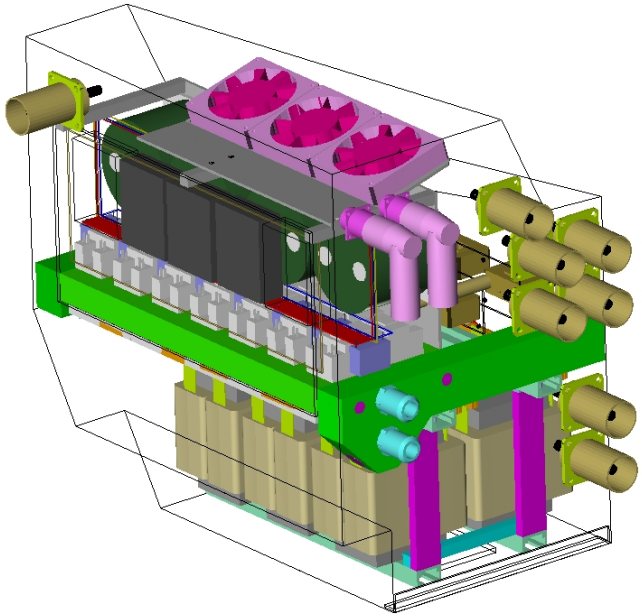




All-Electric Fuel-Cell Powered Car

Voltage DC Link IGBT Converter
Super-Cap in Parallel to Fuel Cell
$400V_{DC}$ (250V)
40kW (60kW)
48kHz Interleaved Switching

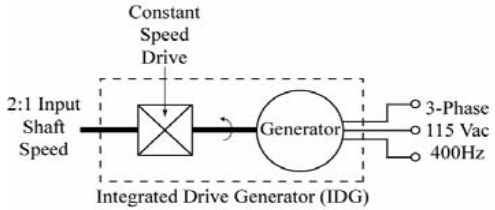


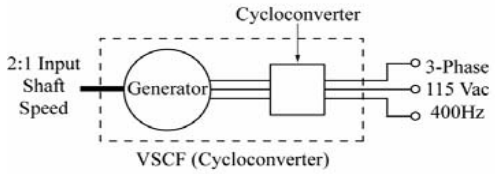


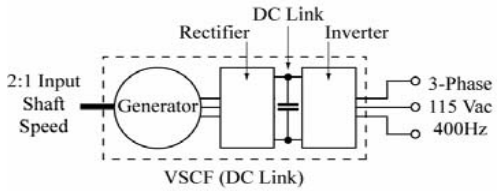
More Electric Aircraft

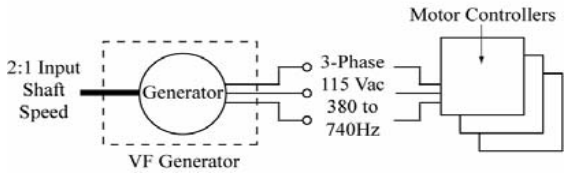
Air Traffic Growth 4.7%/a

Variable Frequency Power Generation
270V_{DC} Power Distribution
Replacement of Hydraulic by Electric System

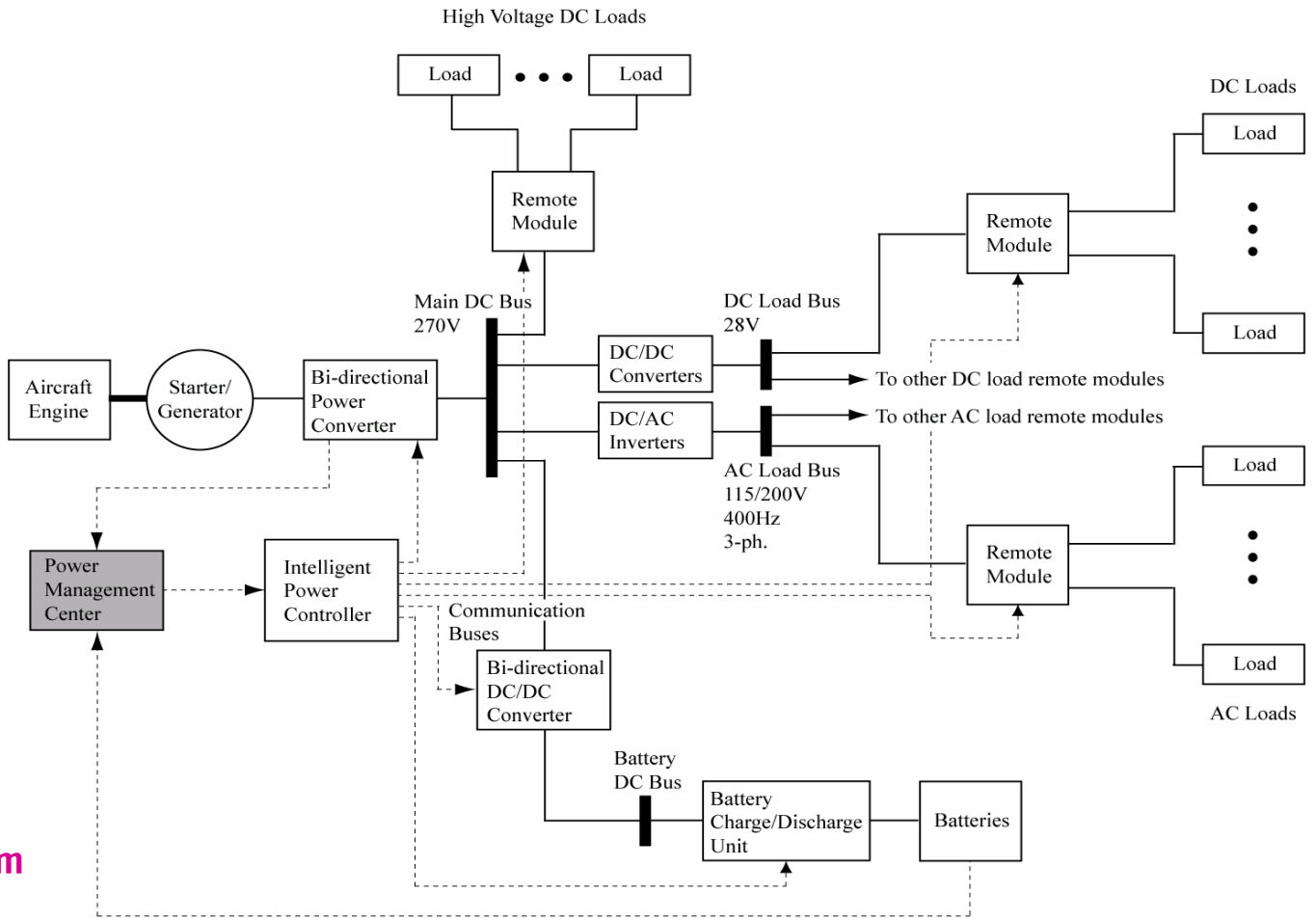






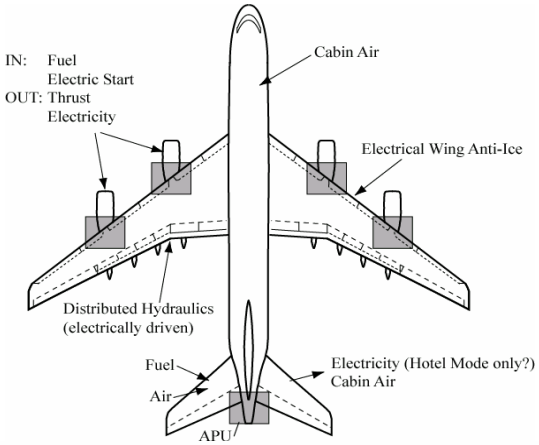


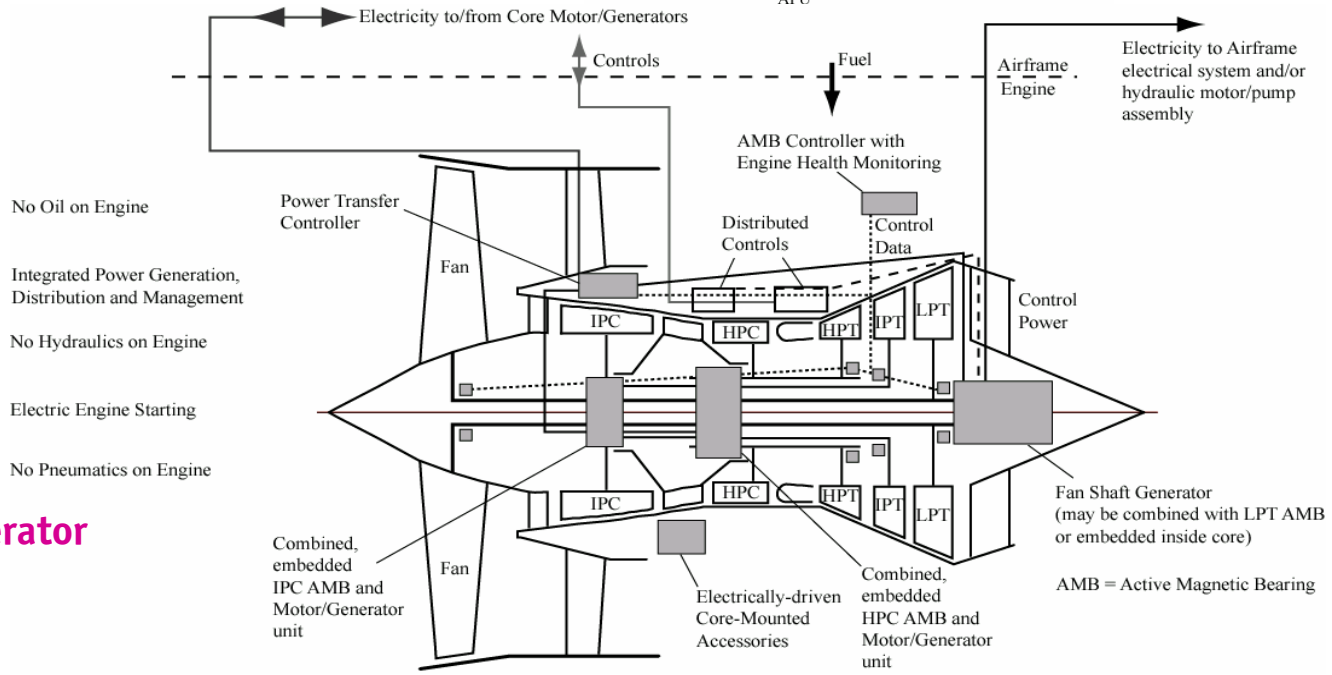
More Electric Aircraft



Power System Architecture

More Electric Aircraft

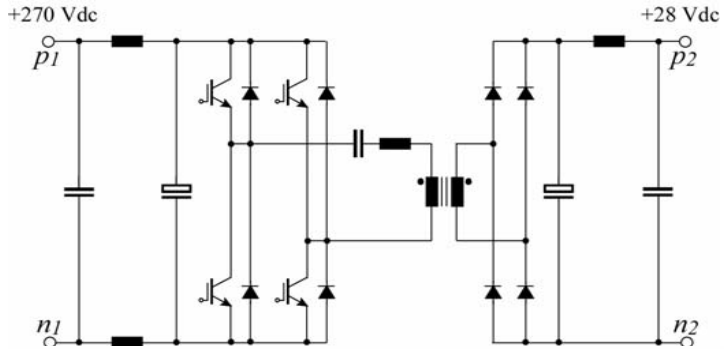




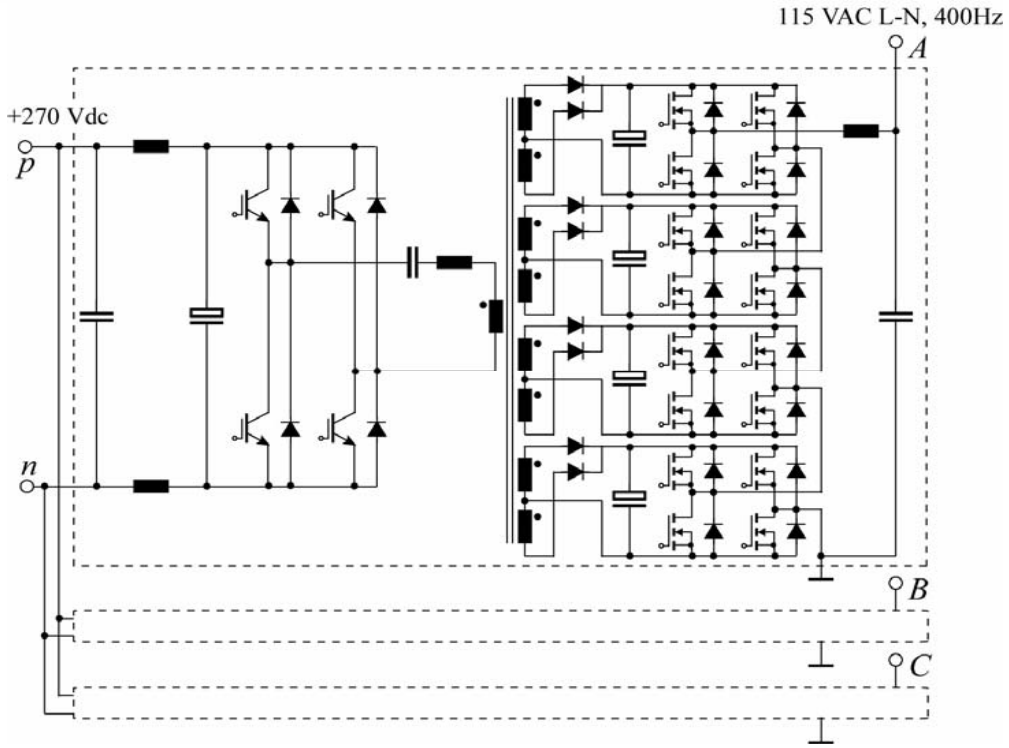
Starter / Generator System

More Electric Aircraft

DC/DC Converter

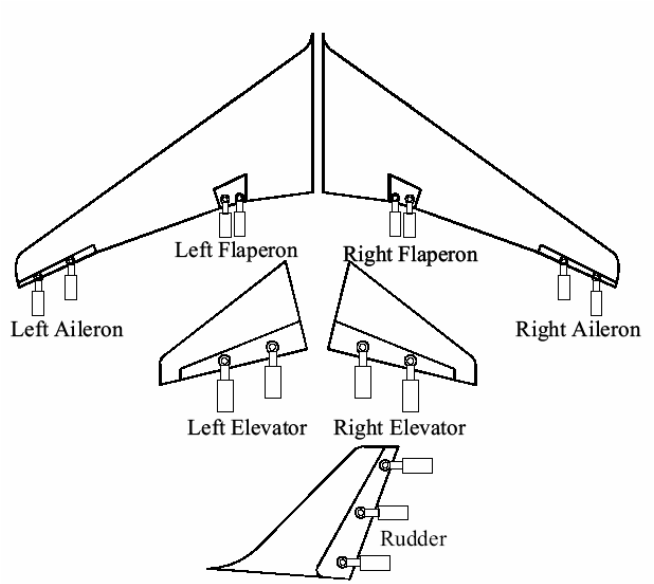


DC/AC Converter Multi-Cell Concept

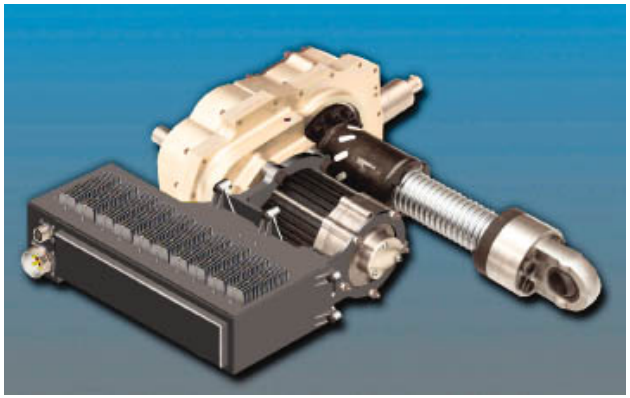


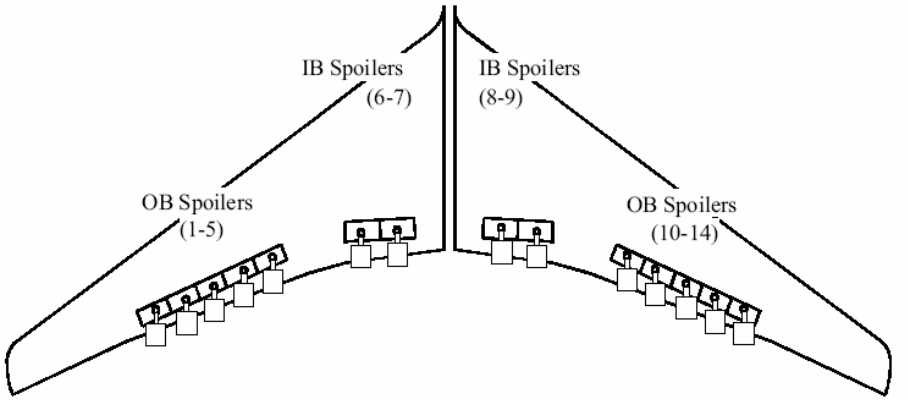
More Electric Aircraft

Flight Control Surface Actuation



EHA Electro-Hydrostatic Actuator
EMA Electro-Mechanical Actuator

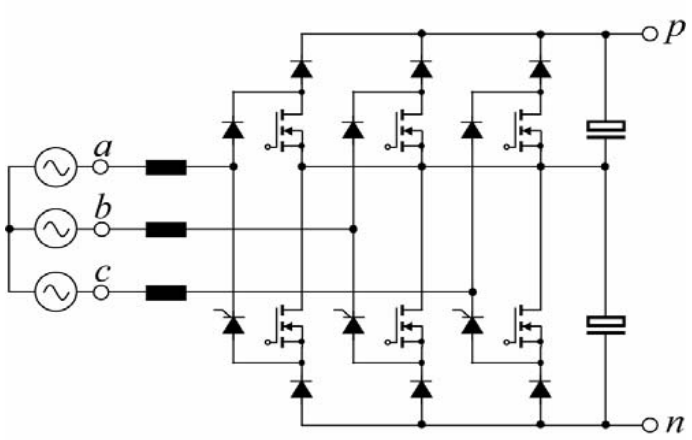




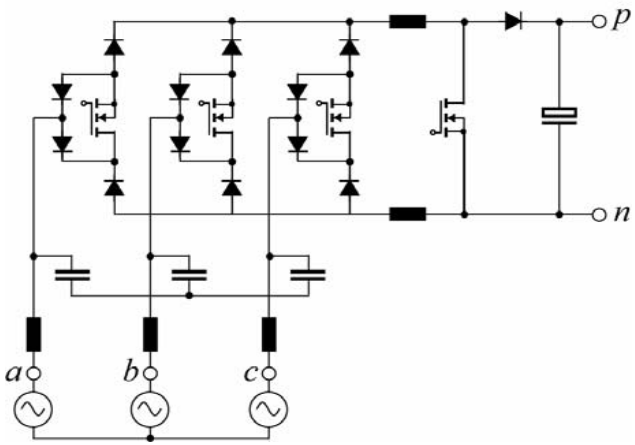
More Electric Aircraft

Three-Phase AC/DC Power Conversion with Low Effects on the Aircraft Mains

Unidirectional Three-Level Boost Converter



Unidirectional Buck+Boost Converter

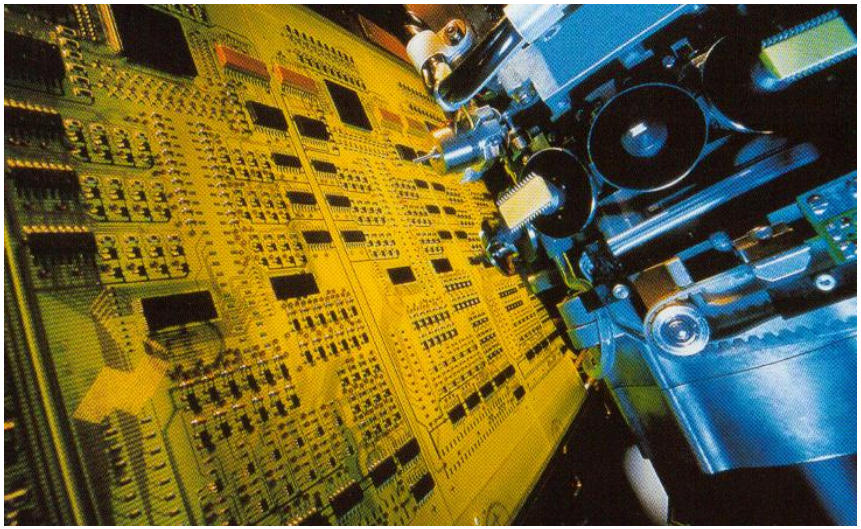


Renewable Energy

Missing Large Scale Energy Storage Technology

Drive Systems

60% of Electric Energy Utilized in Germany consumed by Drives



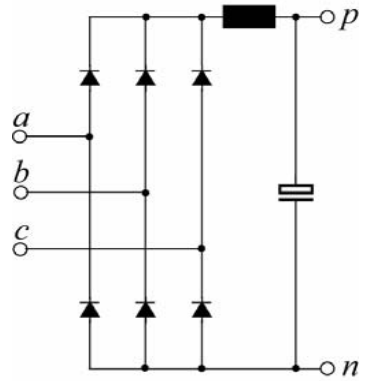
5% Employing Electronic Speed Control
35% Possible Share / 40% Energy Saving Potential (16TWh)

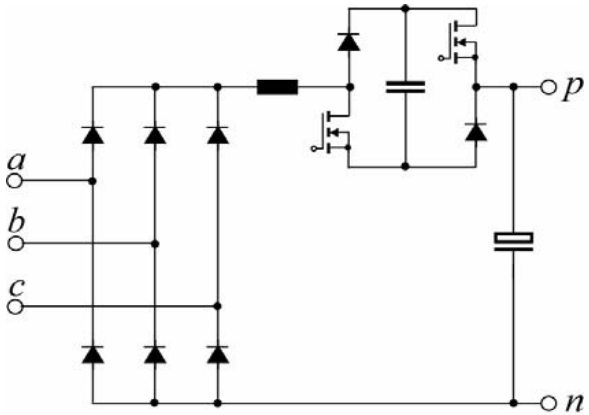
400TWh Drives Energy Consumption in the EU
60% Energy Saving Potential

Drive Systems

Electronic Inductor Unidirectional Utility Interface

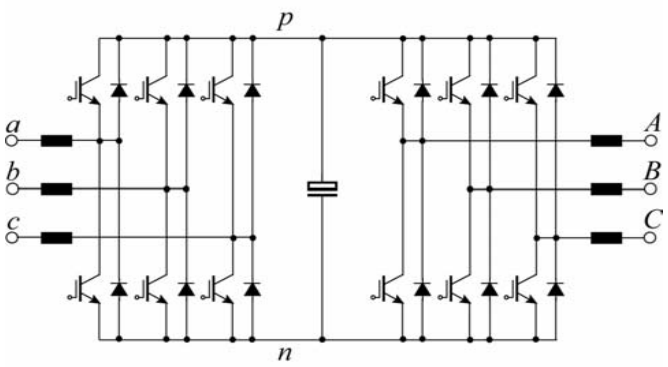
Reduction of Effects on the Mains
η = 99%
10kW/dm^3

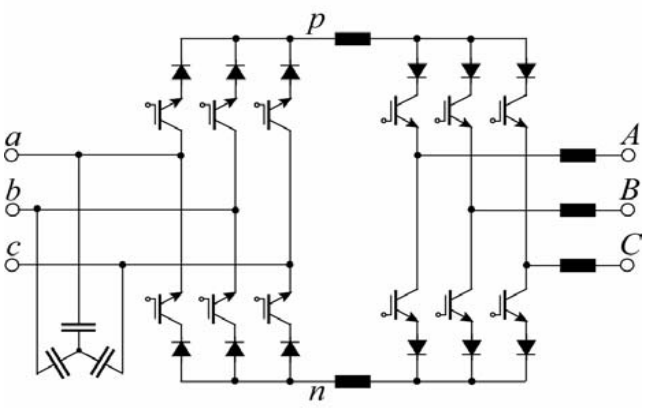




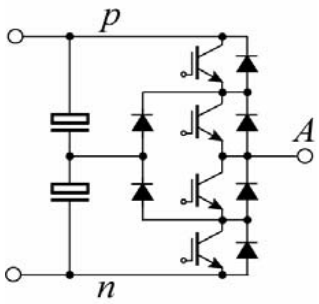
Drive Systems

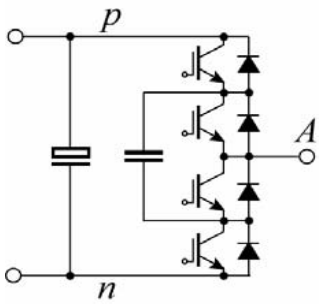
Bidirectional Utility Interface

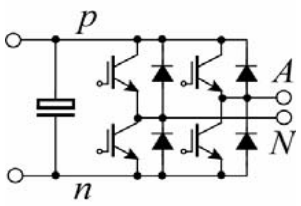




Multi-Level Converter Topologies

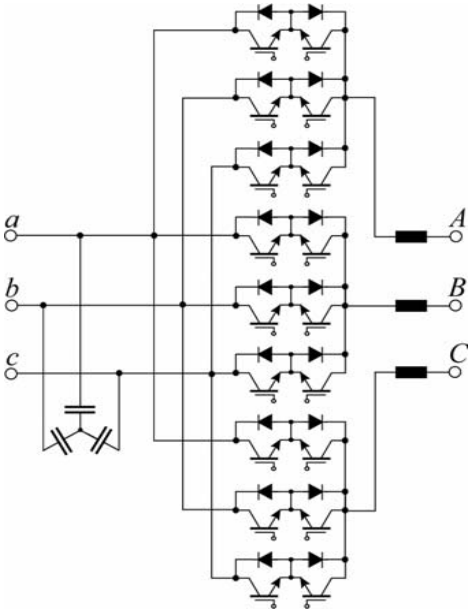




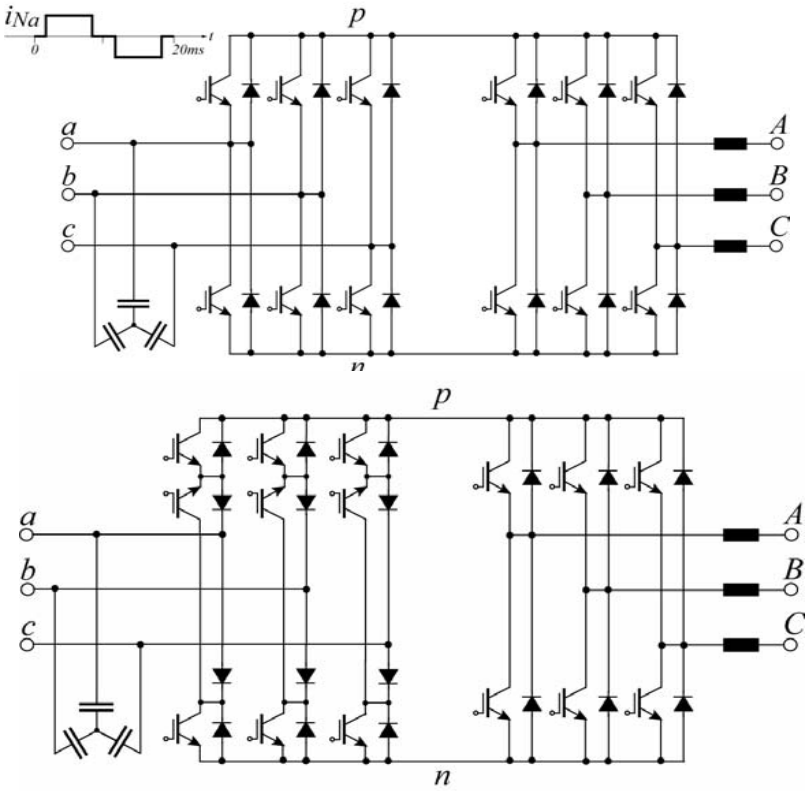


Drive Systems

Matrix Converter



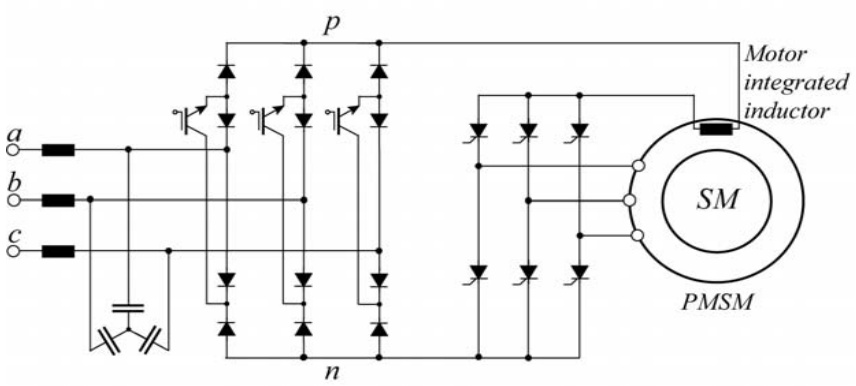
Conventional



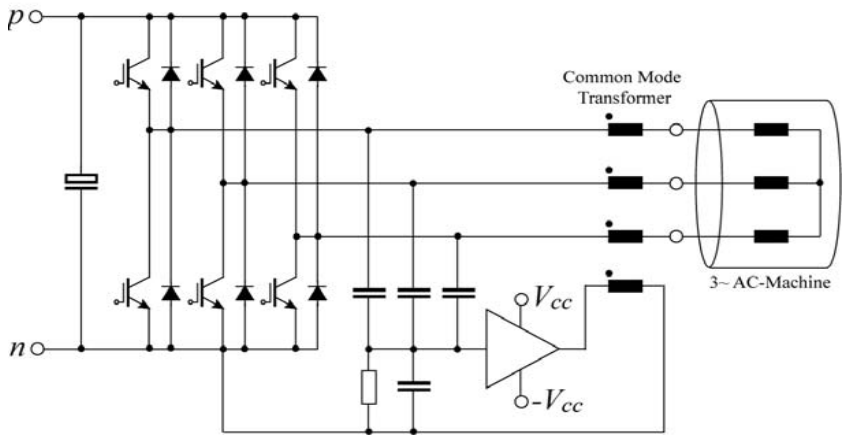
Sparse Matrix Converter

Drive Systems

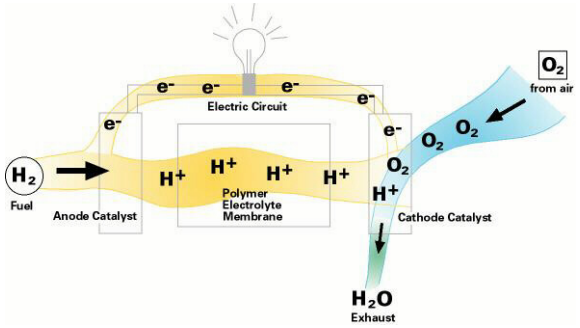
Quasi-Matrix Converter



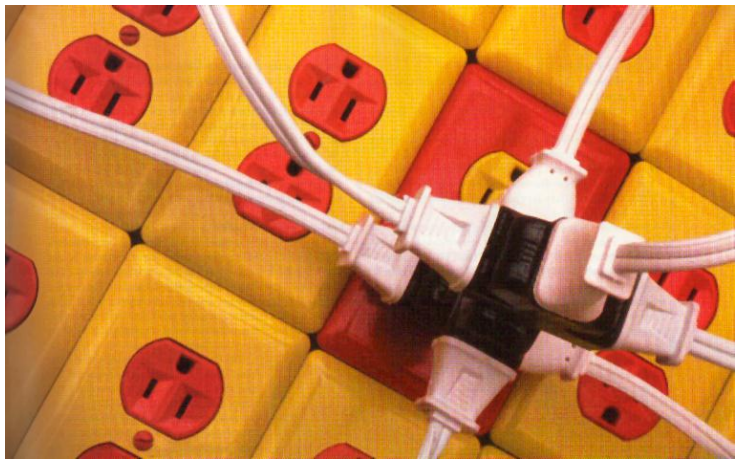
Active Common-Mode EMI Filtering



Distributed Generation and Storage



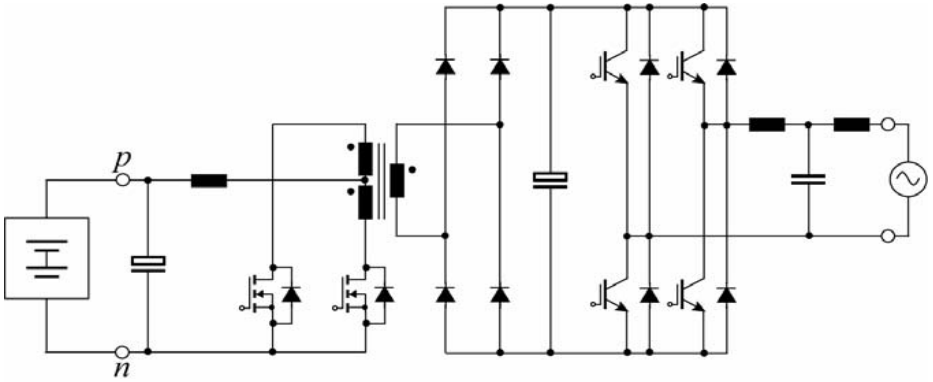
Fuel Cell



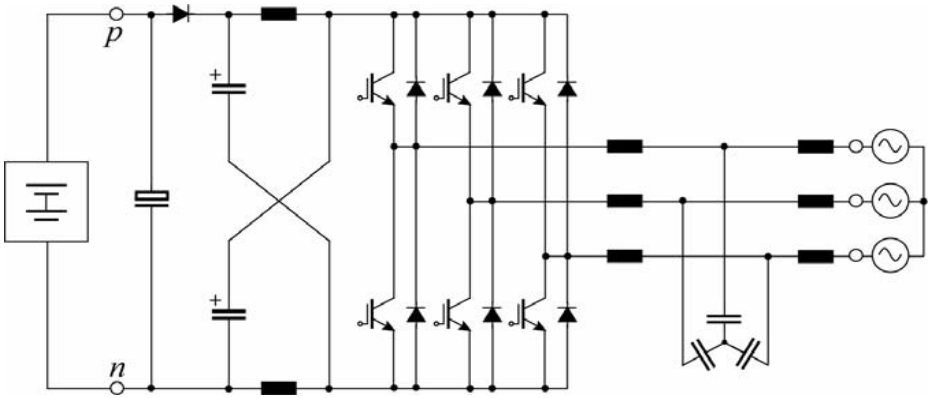
Co-Generation
65% Combined Efficiency
Custom Power / UPS

Fuel Cell Utility Interface

Single-Phase Isolated

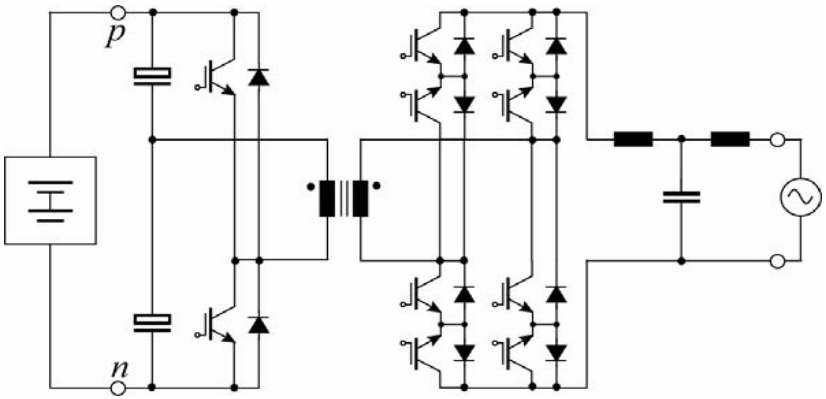


Three-Phase Z-Source Inverter

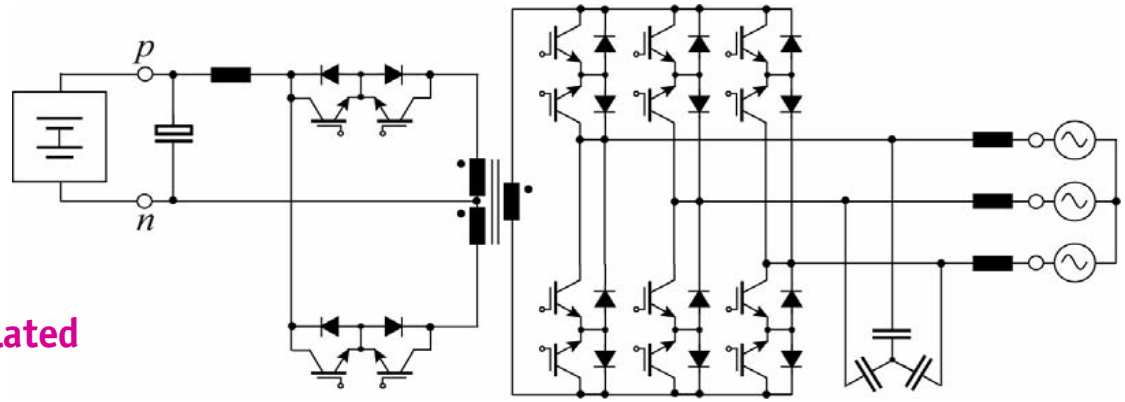


Fuel Cell Utility Interface

Single-Phase High-Frequency Isolated DC/AC Matrix Converter



Three-Phase High-Frequency Isolated Matrix Converter



Power System with Fully Integrated Network Control

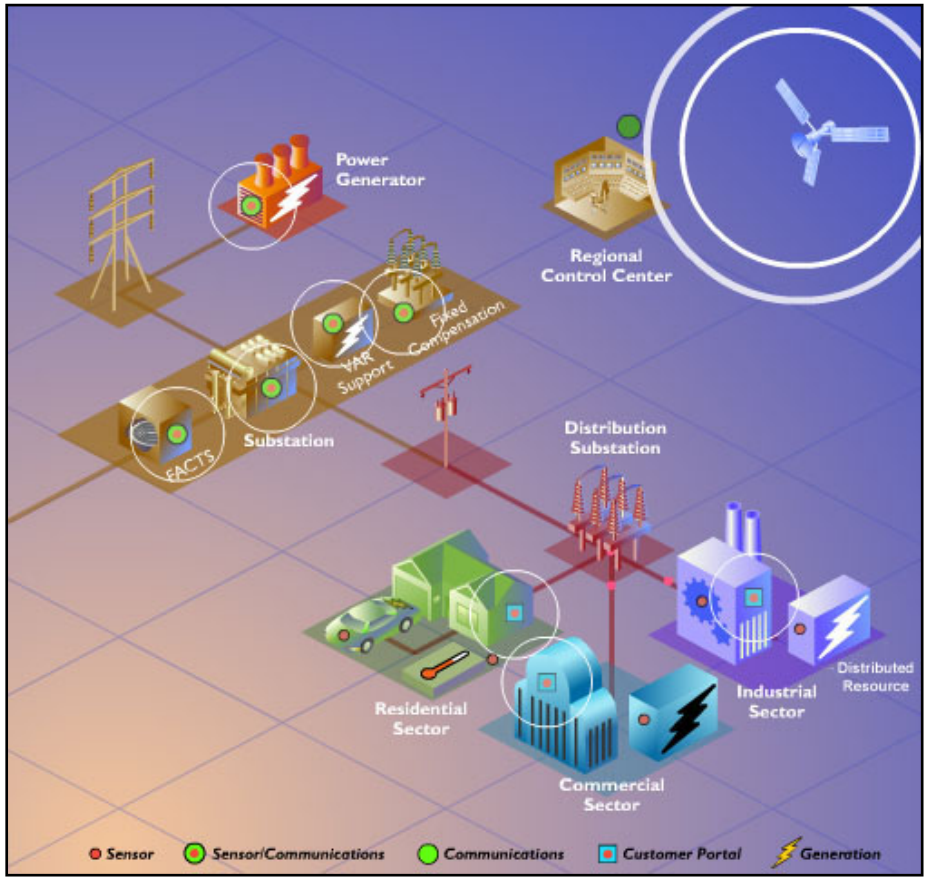
Self-Healing

Wide-Area Monitoring

Power Flow Controlled Instantaneously using Power Electronic Systems

Premium Power and DC Service

Plug & Play of Distributed Resources



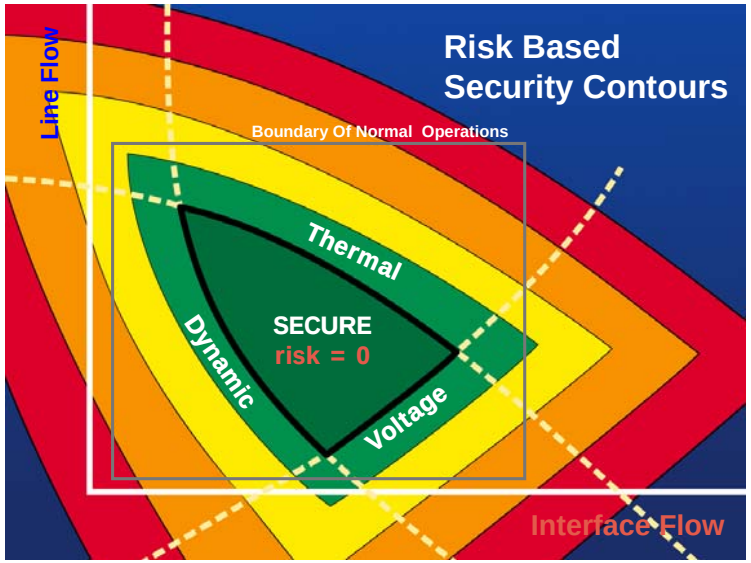
Visualize Critical Information

Displays the Limits of Power Market Activities Imposed by Constraints on the Underlying Power System

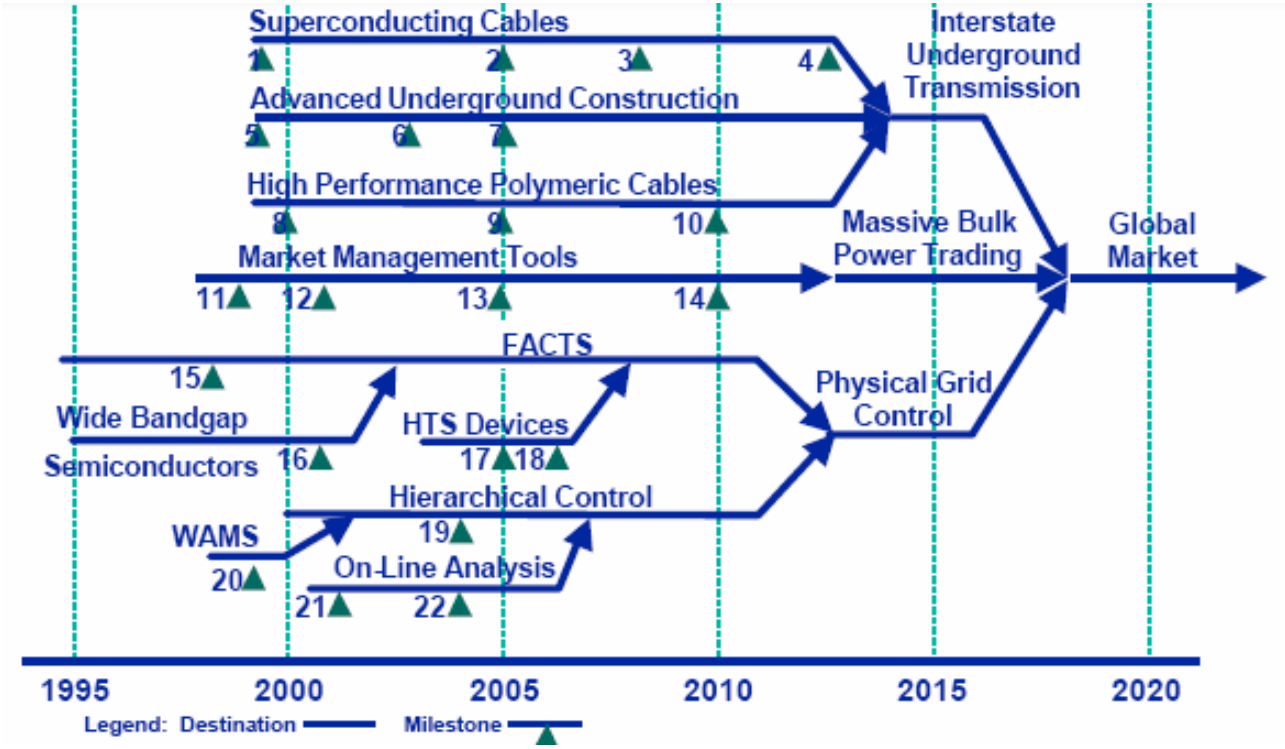
Locates System Bottlenecks

Suggests Combinations of Net Power Import and Export

Promotes Integration of System Reliability and Market Efficiency



Roadmap Tree for Power Delivery Technologies



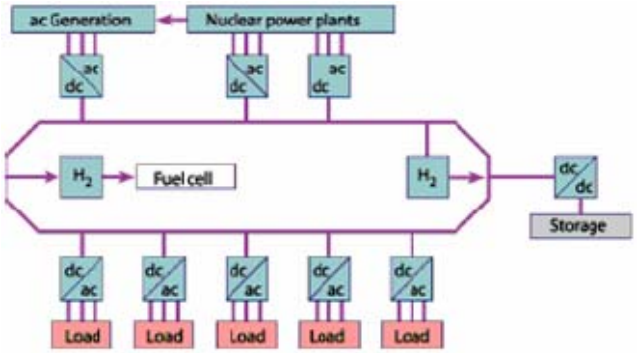
EPRI Electric Power Research Institute

Future U.S. Energy Distribution

Super Grid Concept EPRI

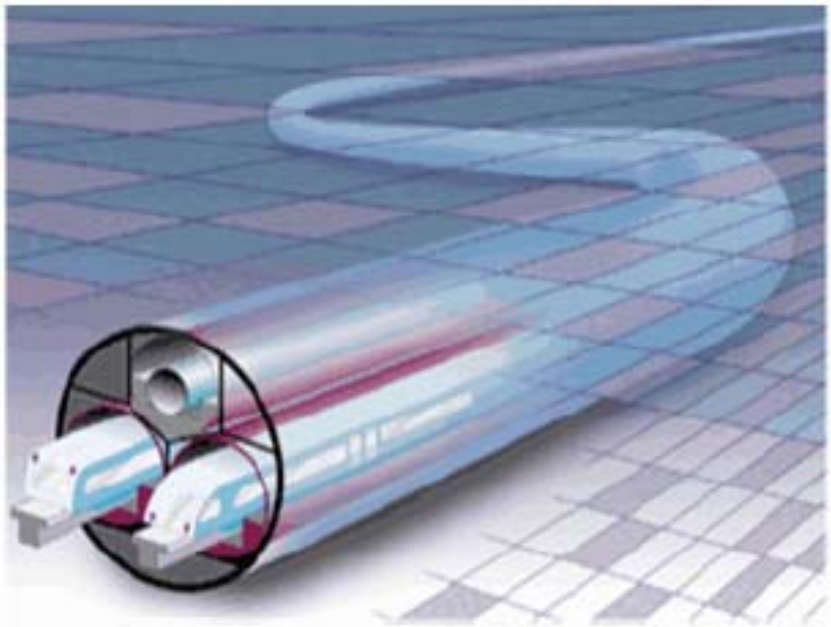
3,000,000 MW Worldwide Electric Utility Generation

700,000 MW in the U.S.
15,000 MW/a added
6,000 MW/a replaced

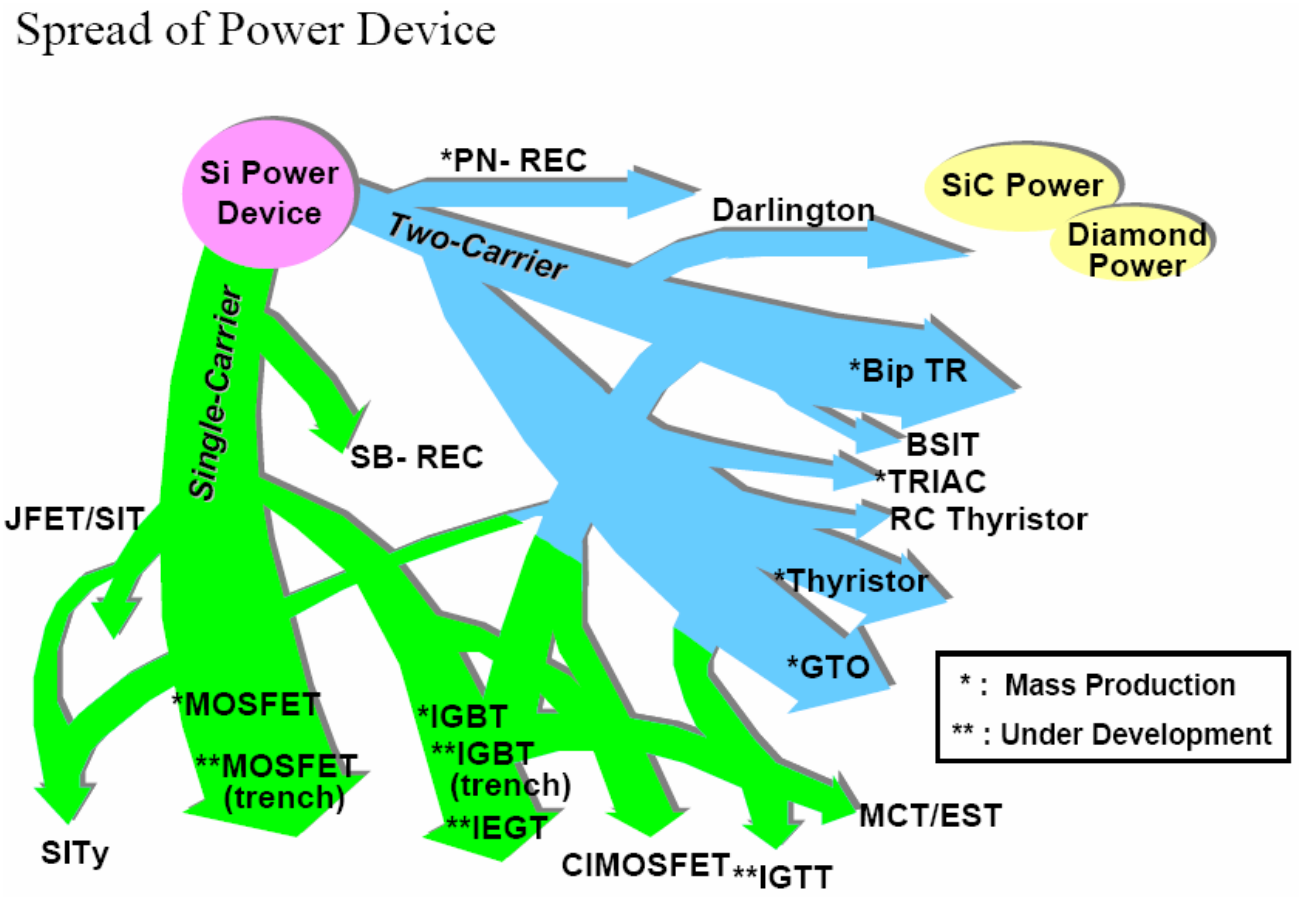


Efficient Coast-to-Coast Underground Transport of Large Amount of Energy – 40...80GW

Simultaneous Delivery of Electricity and Liquid Hydrogen Combined with MAGLEV Systems



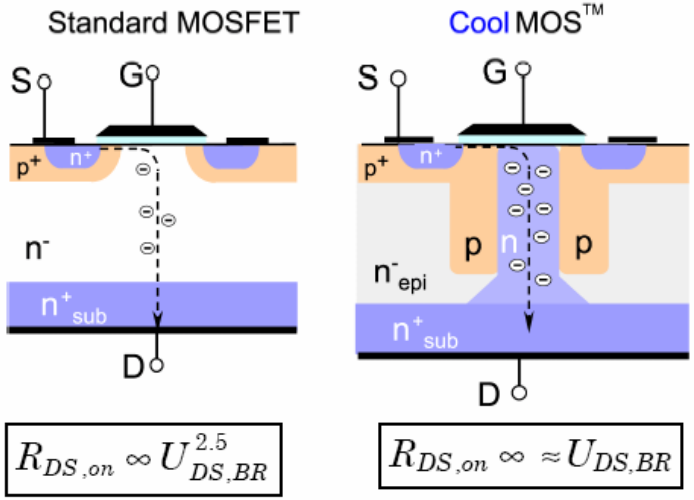
Power Semiconductor Evolution

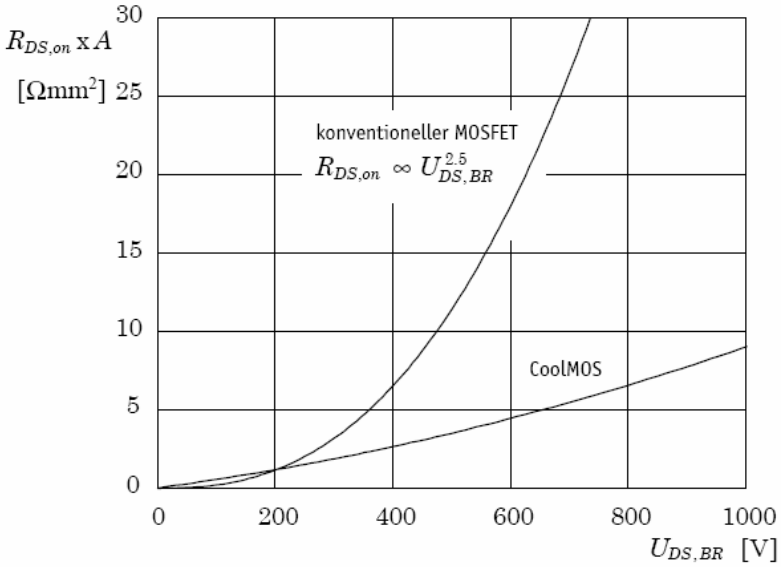


Power MOSFET Revolution

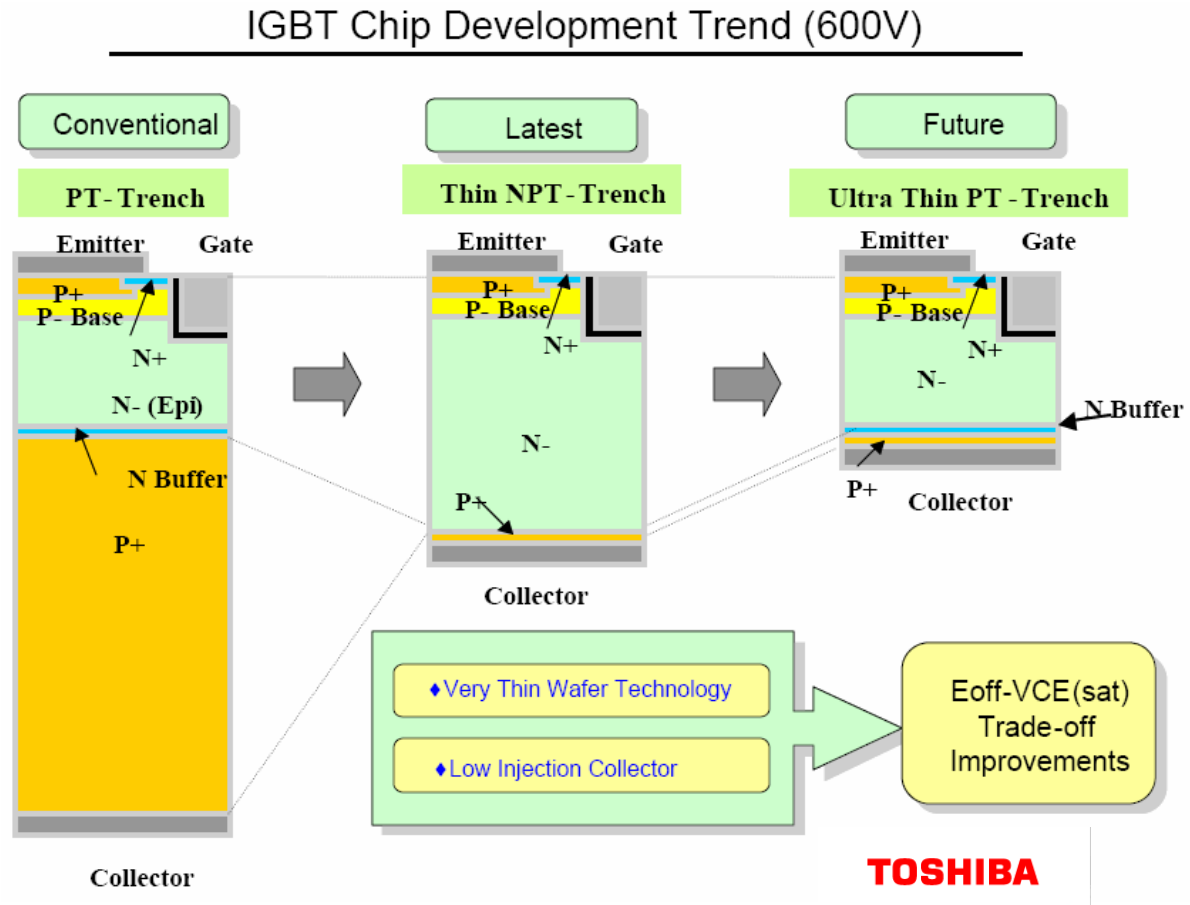
Charge Compensation Principle
High-Doped n-Region / p-Columns

Low On-State Resistance
50V V_{DS} Depletion Threshold
Space Charge Region Extends Across Epi-Layer
High Breakdown Voltage
Capacitive Dynamic Behavior





Evolution of IGBT Technology



Trench Technology
Field-Stop Concept

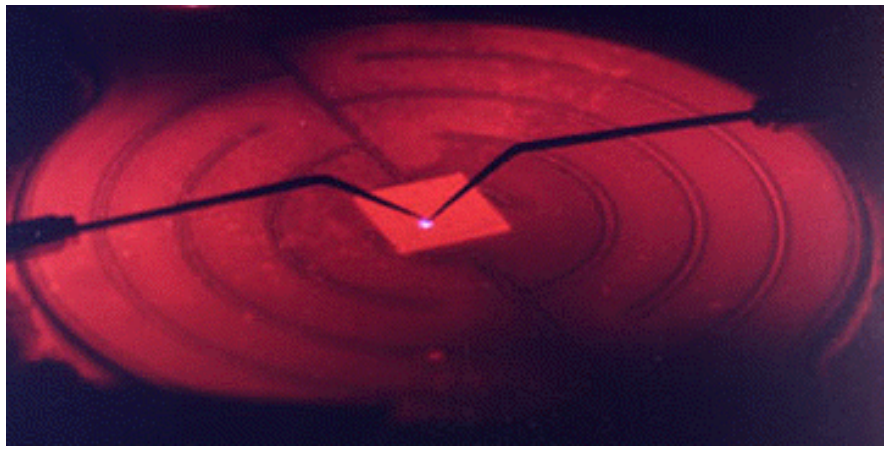
power electronics in motion
eupec

600V IGBT^3
First IGBT Rated for
T_j = 175°C

SiC Power Semiconductor Devices

Advantages SiC / Si

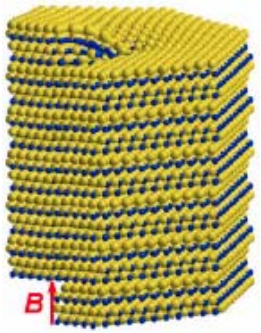
Bandgap (eV@300K)	2.9 / 1.1
Max. Operating Temp. (K)	>900/ 425
Breakdown Voltage (10^6V/cm)	4 / 0.3
Thermal Conductivity (W/cm.K)	5 / 1.5

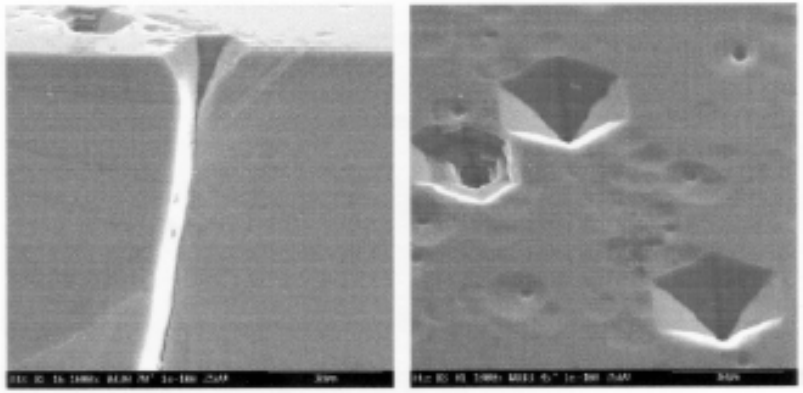


SiC Rectifier Diode Probe-Tested at 600°C

SiC Power Semiconductor Devices

Challenges





Cross section Top view

SiC Wafer Defects – Micropipes and Screw Dislocation
<5/cm²
Low Processing Yield

Defect Density Required for 1200V/100A Devices <3/cm²

2002 SiC Wafer Production Capacity 94% US Share

High Temperature Packaging Techniques

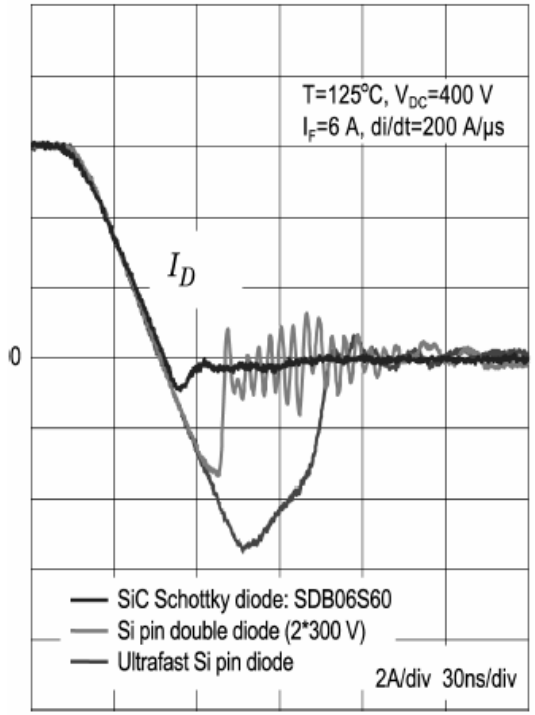
Compatible Gate Drives and Passives

SiC Power Semiconductor Devices

SiCED
A Siemens Company

600V SiC Schottky Diode

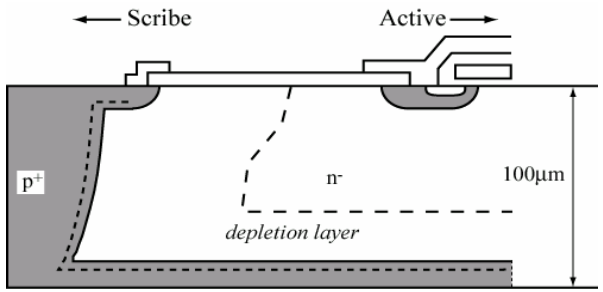
Positive Temp. Coefficient of V_F
No Reverse Recovery Current

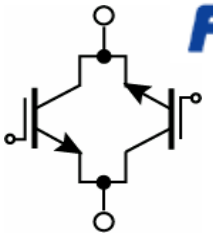


SiC Schottky Diodes	600V	35A
	1200V	25A
	1700V	20A
SiC J-FETs	1200V	5A /10A
	1800V	3A / 8A

Si Power Semiconductor Development

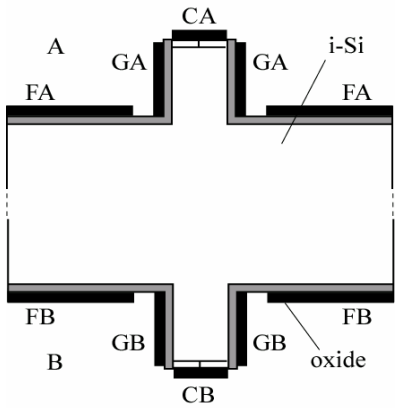
Reverse Blocking IGBT

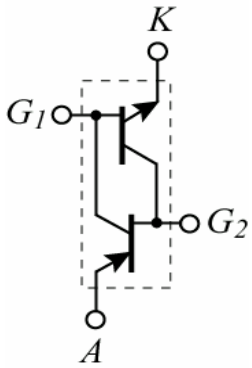




e-Front runners

Monolithic Bidirectional Switch





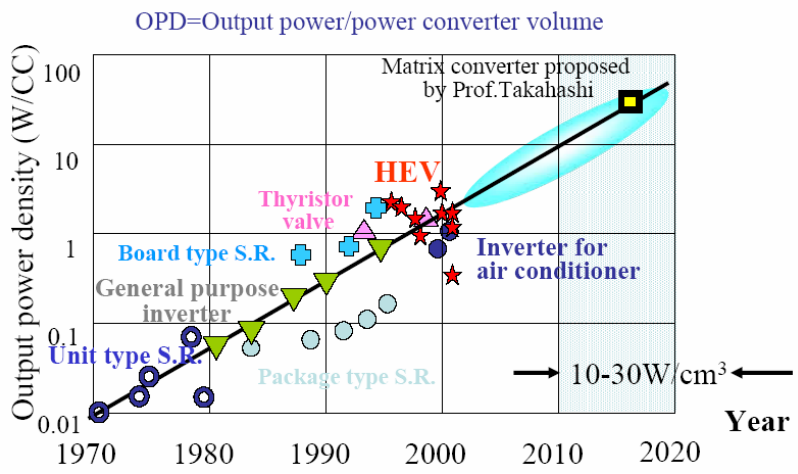
Dual-Gate IGCT

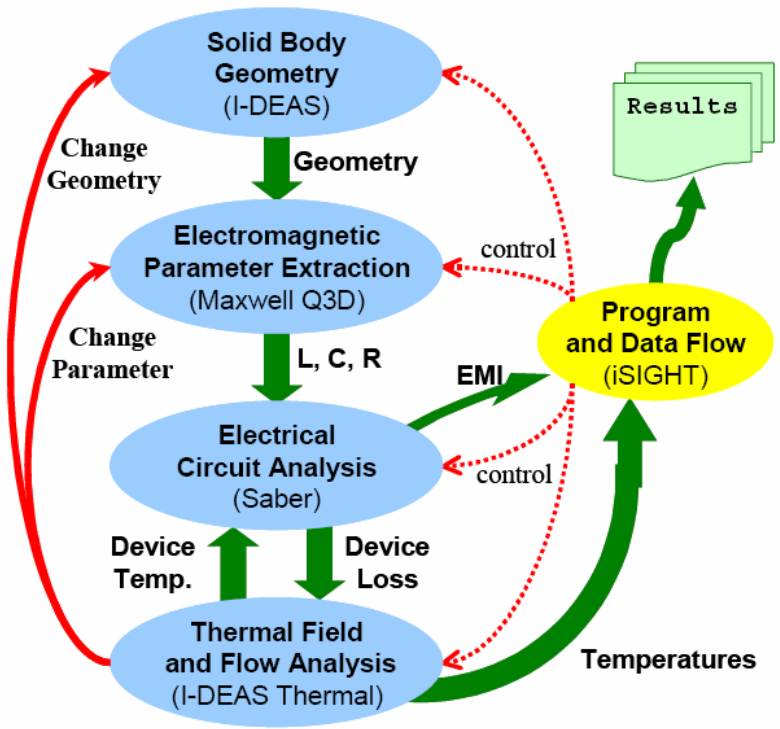
ABB

Future Developments

System Design Integrated Multidisciplinary Modeling and Analysis Circuit/Control/Thermal Electromagnetic/ Mechanical CAD

Power Density 2kW/dm³ → 50kW/dm³



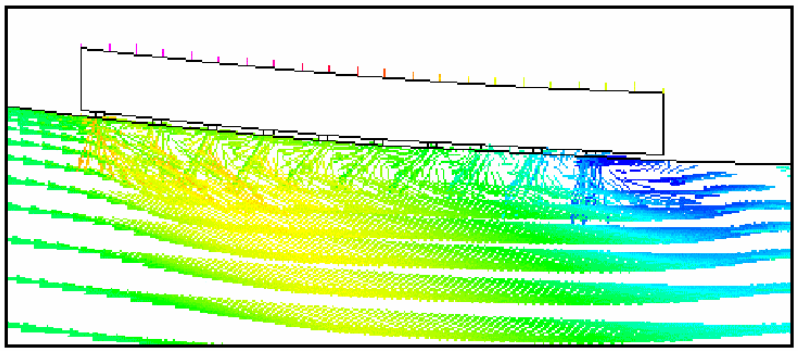


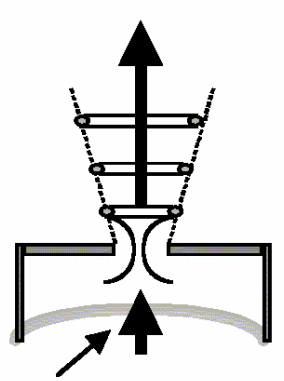
Advanced Packaging and Active Cooling Schemes

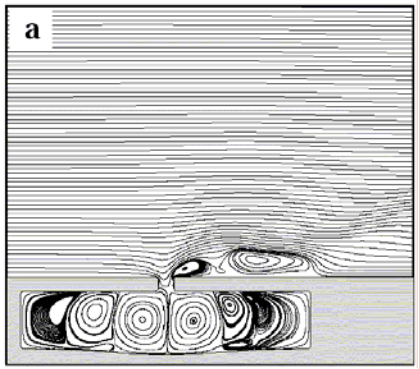
Power Loss Density 100...1000W/cm^2
High Ambient Temperature Applications
High Junction Temperature WBG Devices
Advanced Packaging

Forced Liquid Cooling
Spray Cooling, Shower Power,
Micro Channel Heat Sink

Note: Improved Forced Air Cooling by
Synthetic Jets / Acoustic Streaming







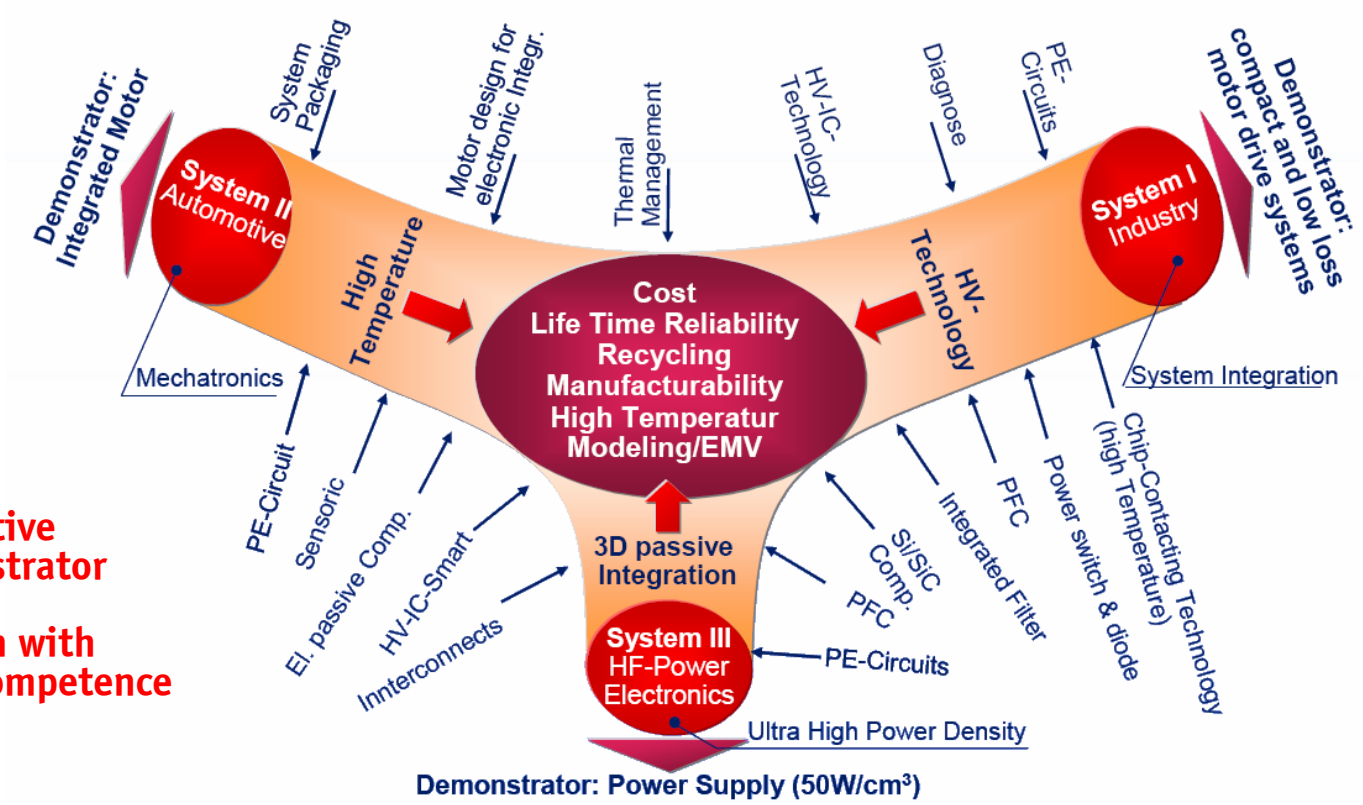
Power Electronics Research Centers

European Engineering Center for Power Electronics

Founded in 2003

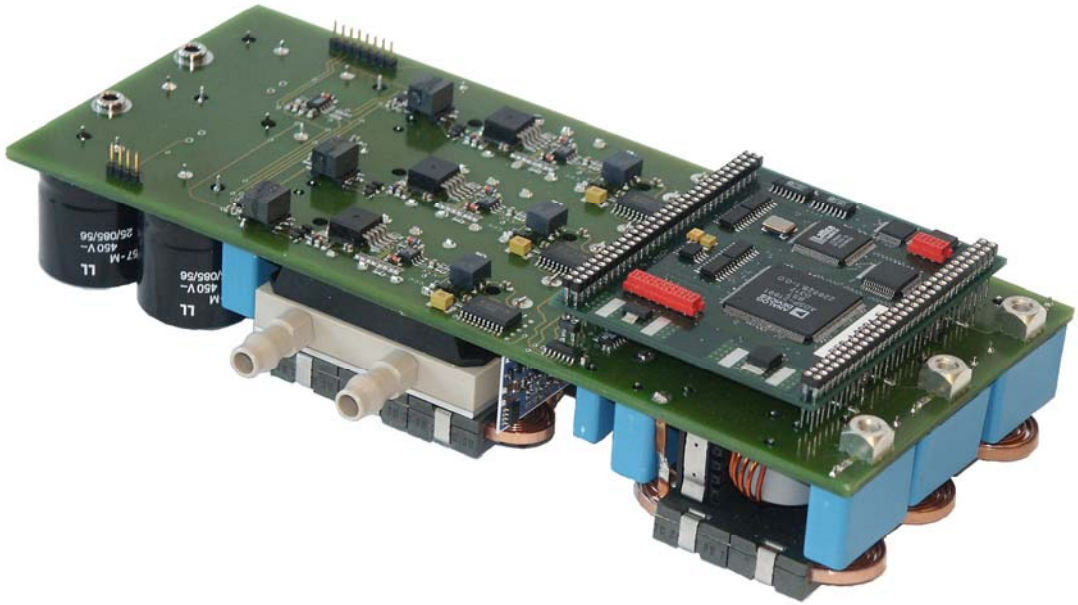
14 Industry Members

Pre-Competitive ECPE Demonstrator Program in Collaboration with University Competence Centers



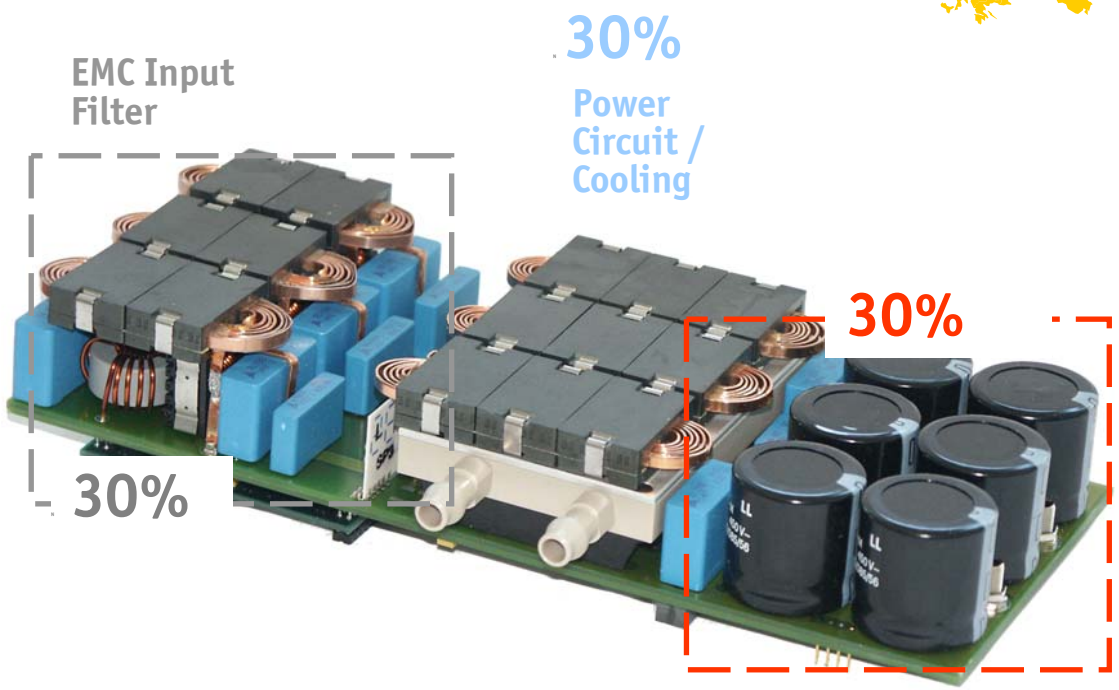
Three-Phase 1-U Power Supply Module

Specifications 10 kW
3-Φ 480V_{AC}
800 V_{DC}
500 kHz
10 kW/dm^3



COOLMOS / SiC-Diodes
Micro-Channel Heat Sink
High-Speed DSP-Control
Flat Magnetics
HBW & CMR Current Sensing

Partitioning of the Converter Volume



Main Share of Passive Components

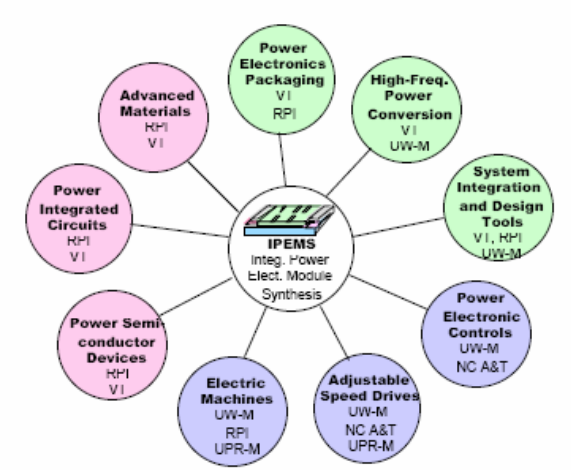
Increase of Switching Frequency
Active EMI Filtering

Electrolytic Capacitors

Power Electronics Research Centers

CPES

- Center for Power Electronic Systems, USA
- Consortium of 5 Universities 70 Industrial Partners
- IPEM Approach, Research on Fundamental Knowledge/ Enabling Technology/Engineered Systems



AIST

- PERC, Power Electronics Research Center, Japan, coordinated by the National Institute of Advanced Science and Technology
- Industry-Academia-Government Collaboration Research
- Research focused on Ultra-Low-Loss Power Device Technology (SiC, GaN)

Future

Power Electronics is the Key and Enabling Technology for all Kinds of Electric Energy Utilization !