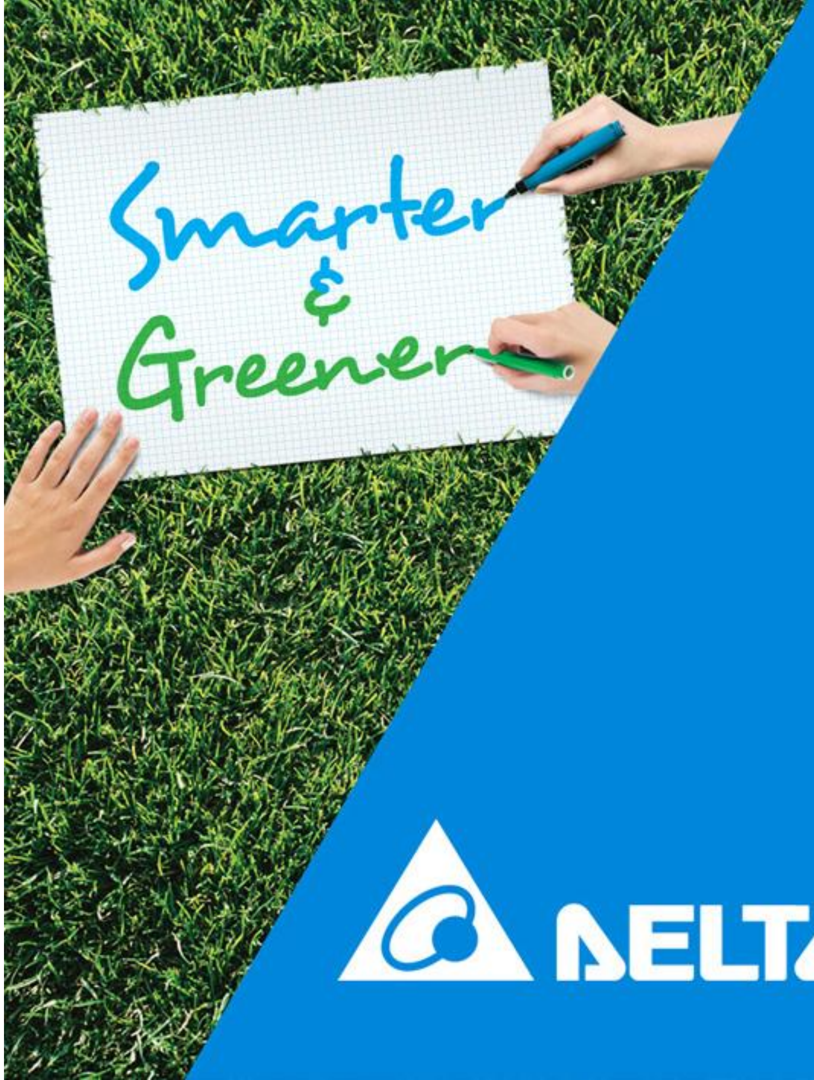
Visions on Power Electronic and Electrical Drive Systems



Dr.-Ing. Peter Wallmeier
30.01.2020

Contents

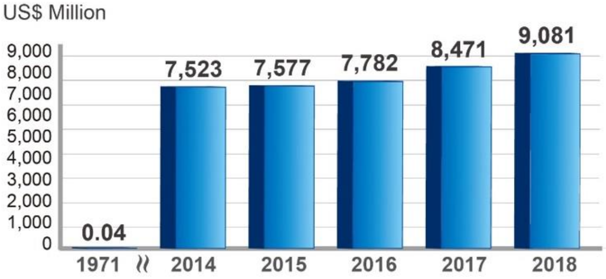
Delta Group Overview

- **Founded in 1971**
- **World’s Leader in Switching Power Supplies and DC Brushless Fans**
- Dedicated to providing:
  - Telecom / Datacenter Power Systems
  - Industrial Automation
  - Passive and Magnetic Components
  - Networking Products
  - Visual Displays
  - Renewable Energy and Energy Storage
  - EV Charging Infrastructure

Bruce Cheng
Founder and Honorary Chairman

Yancey Hai
Chairman

Worldwide Revenues



Delta Global Operations

~450 Eng.

	Asia-Pacific	Americas	EMEA	Total
Sales Offices	110	22	43	175
Plant Sites	31	3	3	37
R&D Centers	49	8	12	69

DES - Global Operations

150

Teningen, Germany

300

Soest, Germany

East Kilbride, UK

Fremont, USA

Raleigh, USA

Hangzhou, China

Bucharest, Romania

Bangkok, Thailand

Dubnica, Slovakia

R&D
Adv.R&D
Production
Sales

DES - Delta Energy Systems History

Locations	 Soest	 Teningen
	History	
Founded	1906	1930
Key Business Stations	Quandt Group CEAG ABB ASEA BROWN BOVERI ascom	FRAKO ascom
Since 2003	DELTA Delta Energy Systems (Germany) GmbH	

Business Categories

Power Electronics

Components
Embedded Power
Automotive Electronics
Merchant & Mobile Power
Fans & Thermal Management
Consumer Power- Innergie

Automation

Industrial Automation
Building Automation

Infrastructure

ICT Infrastructure
Energy Infrastructure and Industrial Solutions
Visual Display- Vivitek

Power Solutions - Target Applications

Power Systems

- Server
- Networking
- Desktop
- Basestation
- Set Top Box
- Note Book
- Industrial
- Game Console
- Appliances
- Power Tool
- Water Treatment
- High Voltage & Precision

Electicial Vehicle

- On Board Charger
- CCU / Combo
- DCDC
- 48V DCDC
- Bi-Directional OBCM
- EVCC
- DCGM
- BJB
- Auxiliary Inverter
- 4 in 1
- Traction Inverter
- Traction Motor

Infrastructure Energy & Industrial

- EV/HEV Charging
- Wind Generator
- Power Gen. & Mining
- Solar Energy
- LED Display
- Display
- Mat. Handling Vehicles
- Medical

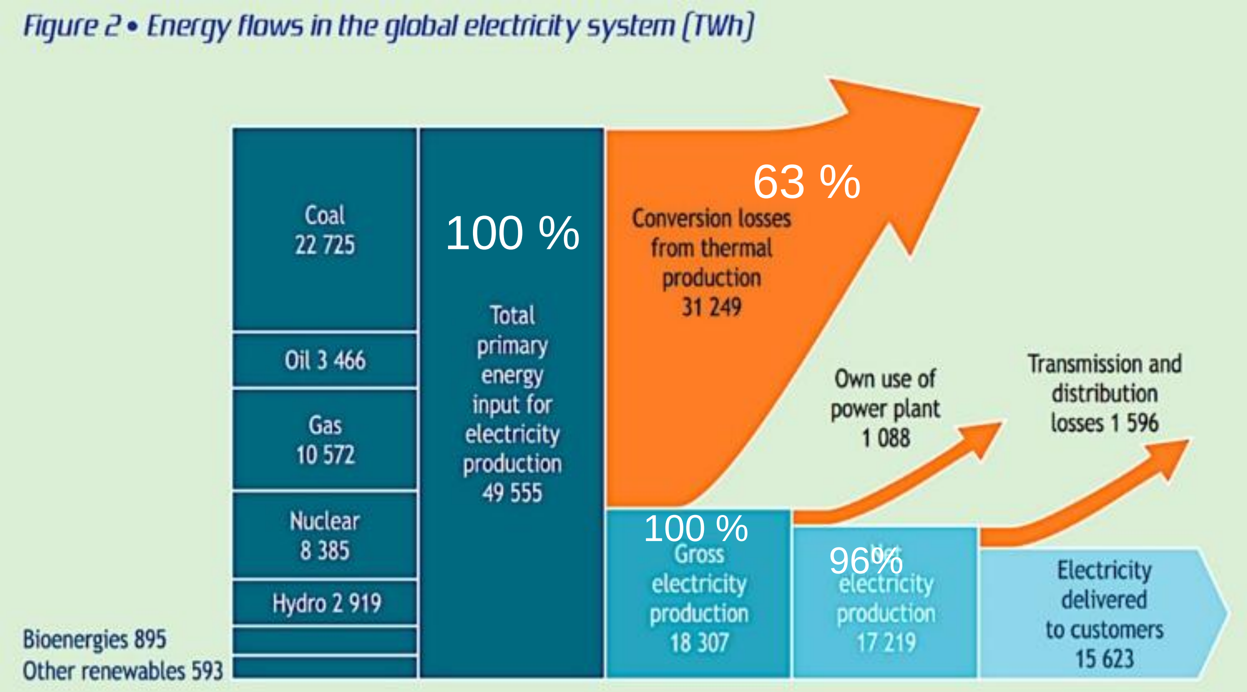
Infrastructure Communication & Telecom

- MCI Power Backup
- Telecom BTS/CO
- Data Center Energy Solutions

ELTEK always on

DNI DELTA NETWORKS, INC.

Efficiency of electrical energy production

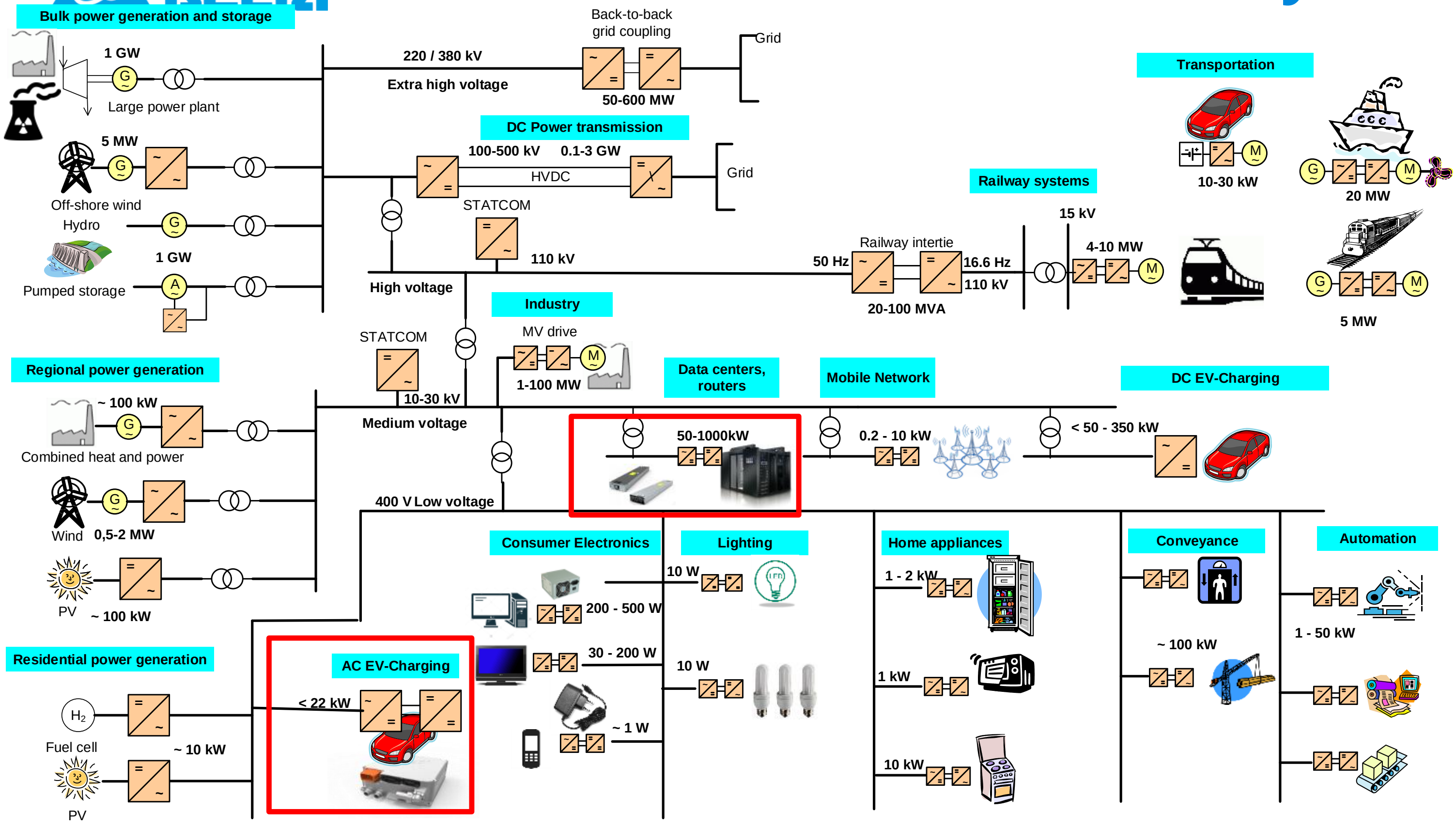


~ 30 %

100 % 91%

Source IEA

PEDS today



Power Electronic Systems in

- generation,
- distribution,
- utilization

of electrical energy with:

- Low renewable content
- High carbon footprint
- Limited functionality
- Not sustainable
- Uni-directional
- Low efficient
- Low intelligence
- No or low load source coordination
- Oversized and space consuming
- Non-resilient

modified from LEA skript, Prof. Böcker, UPB

Today / Future

- Fossil, high GHG emissions
- Petroleum fueled cars
- unsustainability energy infrastructure
- Low efficiency
- Uni-directional
- Low intelligence
- Now or low load source coordination
- Oversized and space consuming
- Non-resilient
- Limited functionality
- Non harmonized policies

- Renewable energy
- Electric vehicles
- Electrified economy
- High Efficiency
- Bi-directional, grid integration,
- smart power delivery
- load-source coordination
- energy storage
- High density
- Resilient Microgrids
- Systems function perspective
- Harmonized WW policies

Requirements to PEDS

Quality

- **Reliability**
- Mission profile
- **Maintenance**
- **Service**
- Repair and installation

Operational and environmental

- Mechanical interface
- Thermal operation / storage
- Cooling fluid chemistry / flow rate
- Temperature / Pressure /
- **Chemical boundary**
- Mission profile Load currents / Load voltage

Environmental compatibility / Dangerous substances

Testing and validation

- Functional tests
- **Quality and reliability tests**
- **Legal requirements**

Requirements to Functional safety (ISO26262)

- **Regulations**
- **Safety relevant requirements / goals**
- **Requirements on production, service and operation**
- **System software integration**
- **Protection of infrastructure**
- **Safe states**
- **Diagnosis**
- **Fire Protection**
- **Contact Protection**
- **Electrical Safety Creepage and Clearance**

Requirement on functionality

- DC/DC Converter
- Charger
- eDrive
- Pedal
- **SW-Architecture**

Requirements to PEDS

Power Characteristics

- Output voltage range and adjustment precision
- Rated power and conversion function
- Power Factor

Mechanical Characteristics

- Size / weight
- Marking
- Installation space / clearance / mounting
- **Endurance strength (Vibration)**
- **Working load from special events (crash)**
- **Handling**

Electronic Design

- **Isolation resistance**
- Electrical I/O (Power / current / voltage / frequency)
- Ripple generation and susceptibility
- Line / load regulation / Dynamic load / Efficiency
- Surge load and power derating (V,C,T)
- Operation states, limited operation, wake up
- EMC (Simulation, test plan)
- Wake up and sleep, **quiecent current**
- Inrush current

Electronic Design contd.

- **Electrical diagnostics**
- Energy consumption of board grid
- **Max. differential mode and common mode capacitance**
- **Jump start / Power down**
- **Cable dimensioning**

Software Design

Acoustic

Technical cleaness

Corrosion

Material Selection

Thermal integrity of operation

Crash Requirement

4. Requirement on integration

- Interface description: mechanical, electrical, communication

PEDS disciplines research areas

Components and packaging:

- Power semiconductors
- Power integrated circuits (PIC), Hybrids, Modules
- Passive components
- Magnetics (SST, FACTS)
- Packaging technologies (Thick-Film, Integration)
- Wide bandgap semiconductor technologies (GaN,SiC)

Circuits:

- Bi-directional
- MHz conversion circuit technology
- Hard-switching & soft-switching
- Single stage power conversion
- Multilevel

Controls:

- High speed digital ctrl for MHz conversion

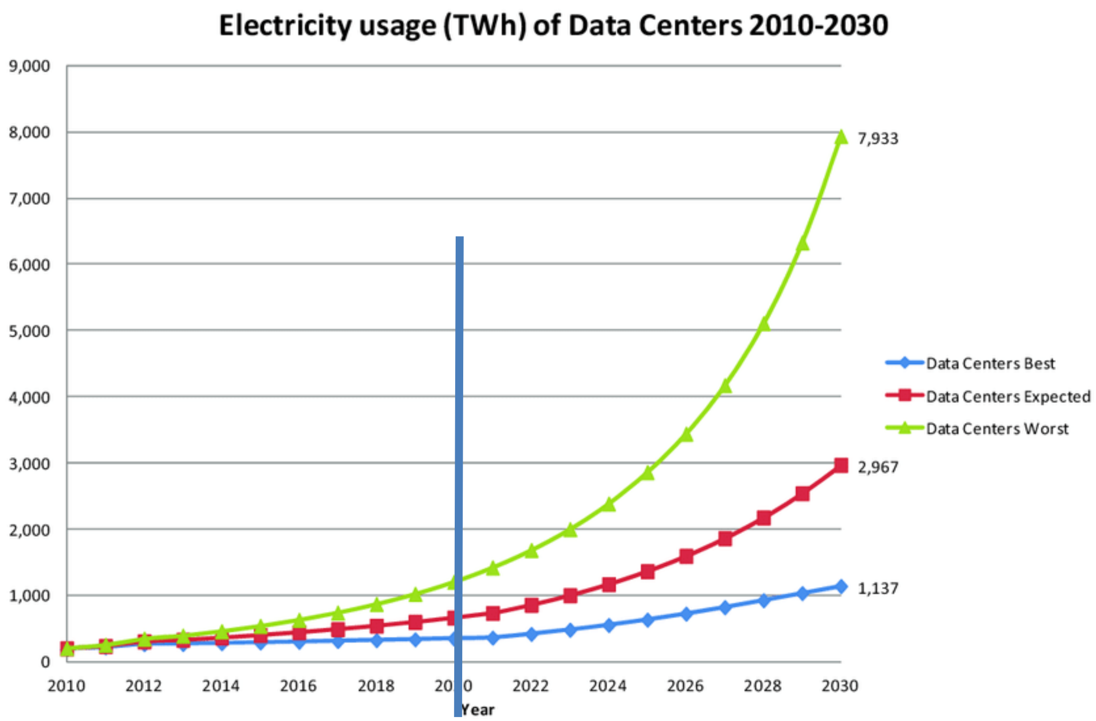
System-Technologies:

- Applications of power electronics in **power systems**
- **Traction & automotive systems**
- **Datacenter and Cloud computing power systems**
- Home appliances, industry & aerospace
- Robotics systems and application
- Renewable energy technologies
- Distributed generation & smart-grid
- Intelligent electronic systems
- **Mobile Networks power systems**
- Thermal management
- EMI

Methods

- Analysis & design of electrical machines
- Modelling & simulation in power electronics
- Power electronics related education /professional development
- Reliability analysis

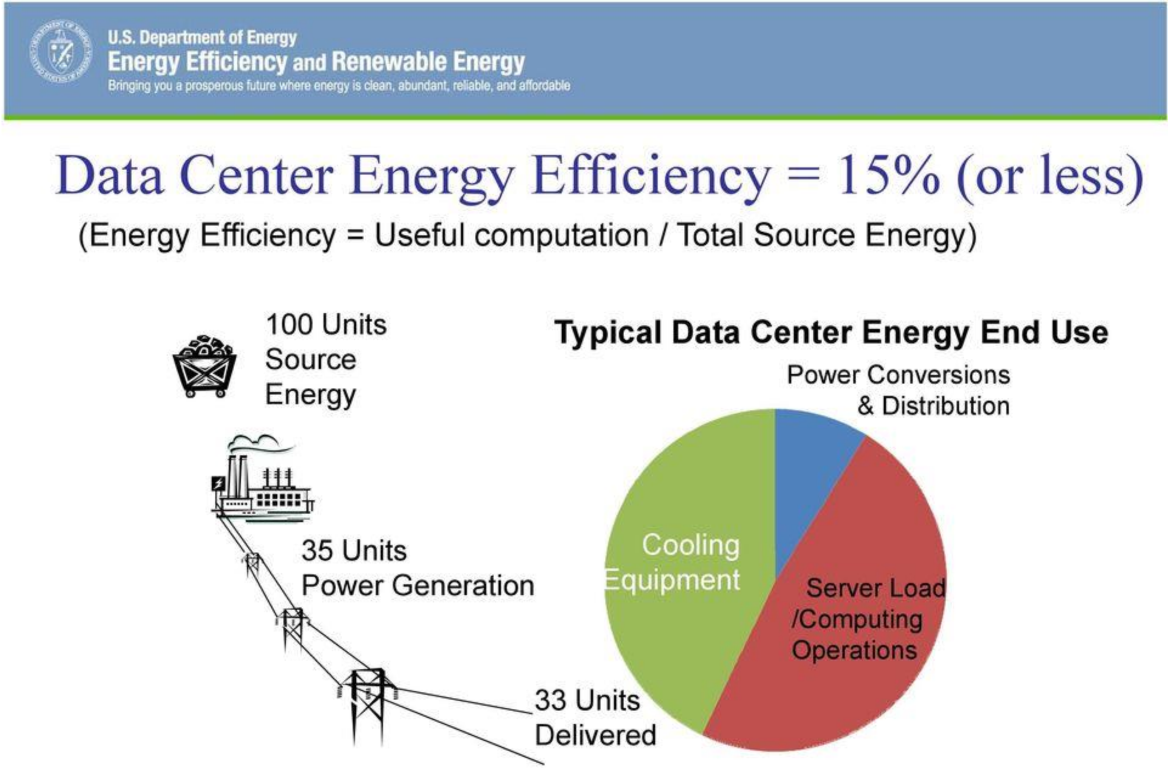
Datacenter energy consumption



~ 2% in 2017
to ~ 12 % 2030
of WW energy
demand

https://www.researchgate.net/figure/Global-electricity-demand-of-data-centers-2010-2030_fig2_275653947

Datacenter efficiency



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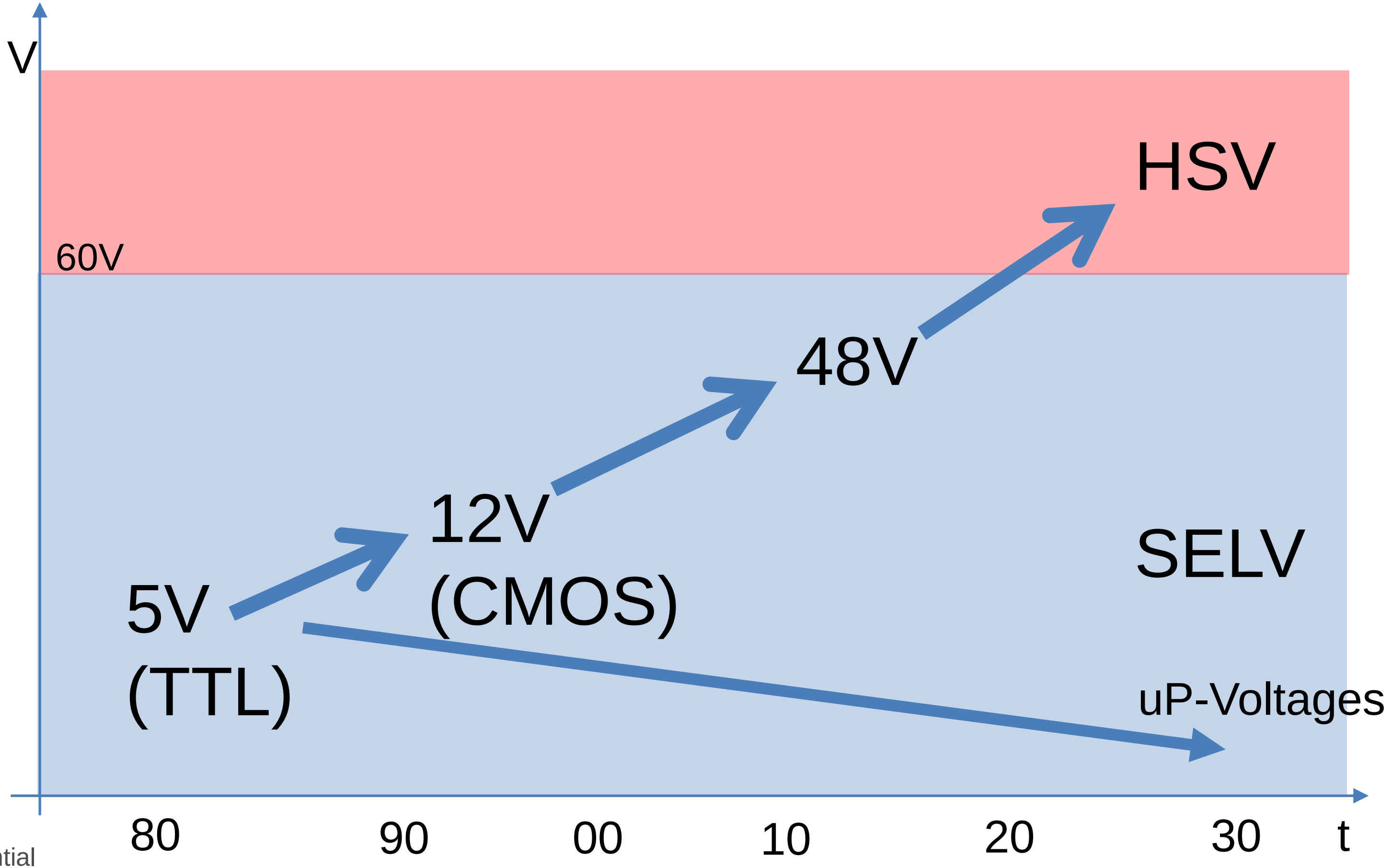
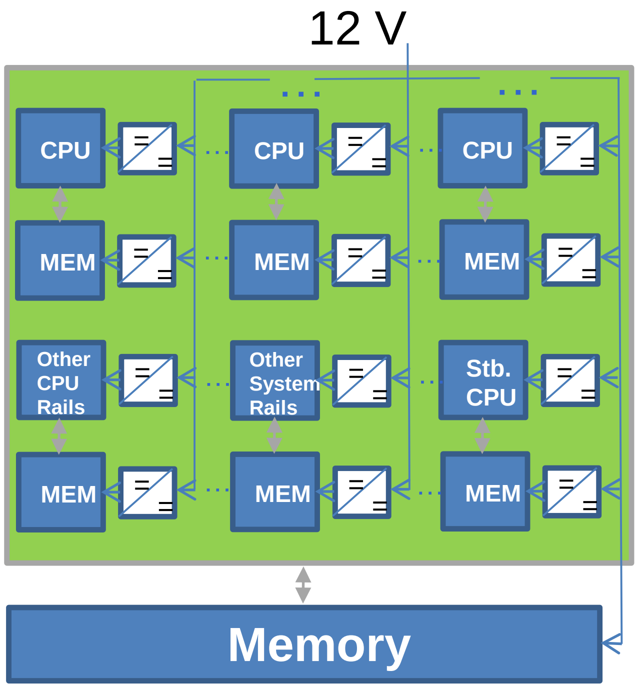
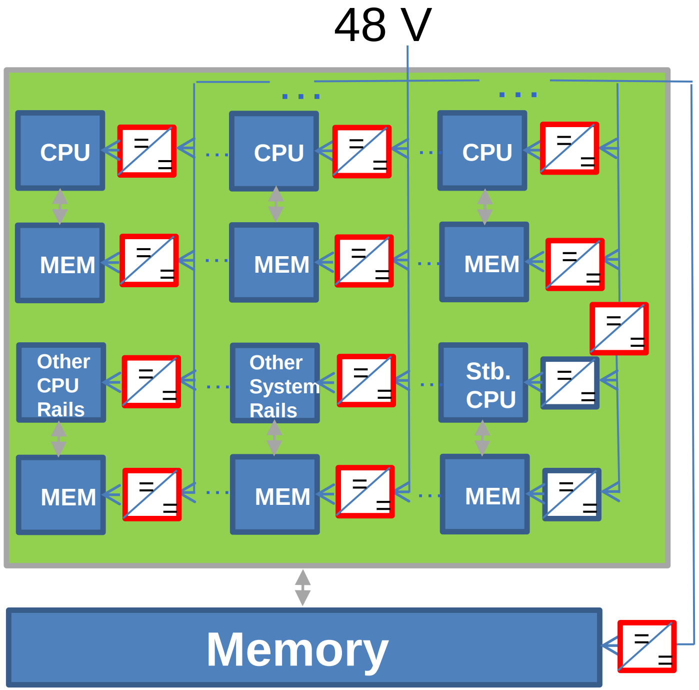
History of uP board input voltages



Motherboard power architecture





- CPU & MEM: PoL VR (Multiphase Buck)
- Other & MEM: PoL VR (Multiphase Buck)
- Max. Current is limited ~ 30A (DOSA)
- Efficiency ~ 93 % @ 1.5 V
- Low cost power conversion

- CPU & MEM: D2D new design 48 V -> PoL
- Low Power Other & MEM: PoL VR (Multiphase Buck)
- Max. current ~130 A
- Efficiency ~ 97 % @ 1.5V
- Higher cost power conversion

Components and packaging

Single Phase AC->12V,48,400VDC

Today(48 V):

Power density: 50 W/in^3 (3 kW/l)
Efficiency:
93,2% @ 10 % Load
97,8% @ 50 % Load
96,5% @100 % Load
FAN cooled

Source: Infineon

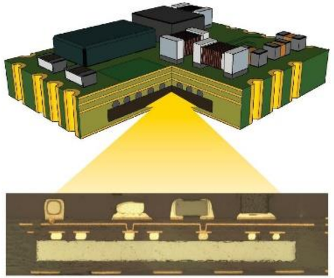
- PCB main component carrier
- Discrete THT and SMT
- Wound magnetics
- Si only

Future:

Power density: 170 W/in^3 (**10 kW/l**)
Efficiency: >99 % pk@50 % Load
No FAN

Ceramic Module

GaN / SiC / WBG



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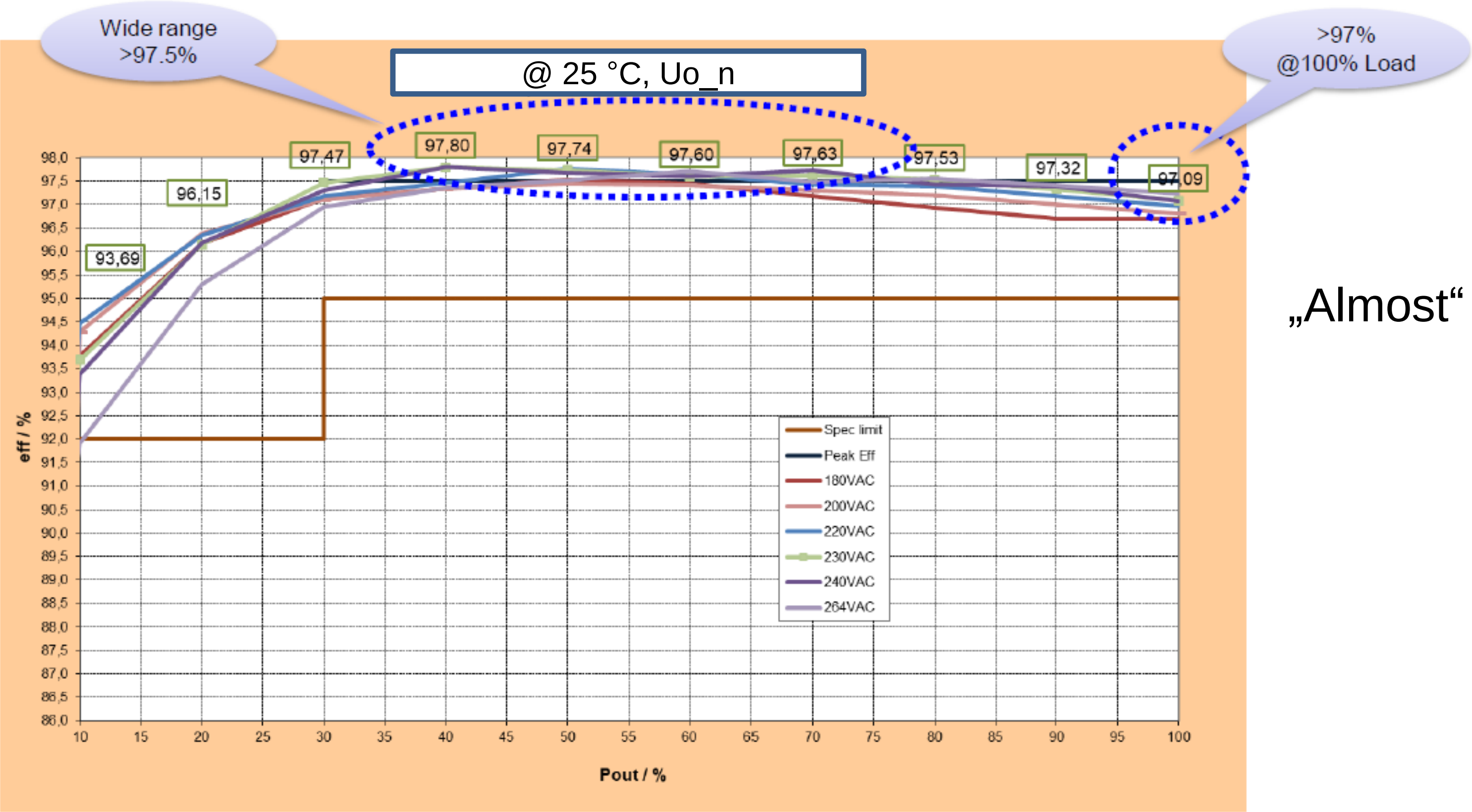
cross-section of embedded module

PCB embedded modules

Efficiency counts



„Almost“ 98 %

Circuits

Single Phase AC-> 12V, 48V, 400V DC

Today:

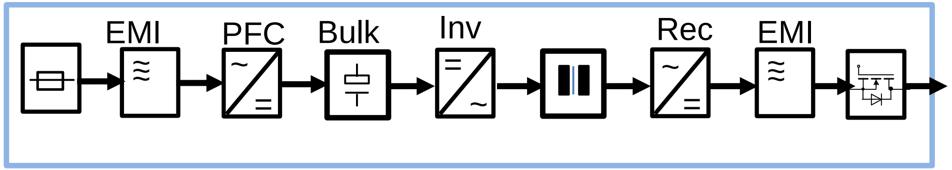
- Two or multistage stage (PFC, DC/DC, Decoupling)
- Uni-directional
- 2 or 3 level
- Up to 200kHz

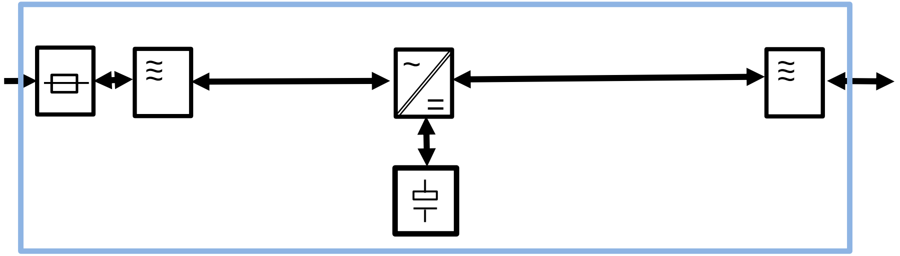
Future:

- Single Stage
  Combine all stages
- Bi-directional
- Multilevel
- MHz

?

Server PSU

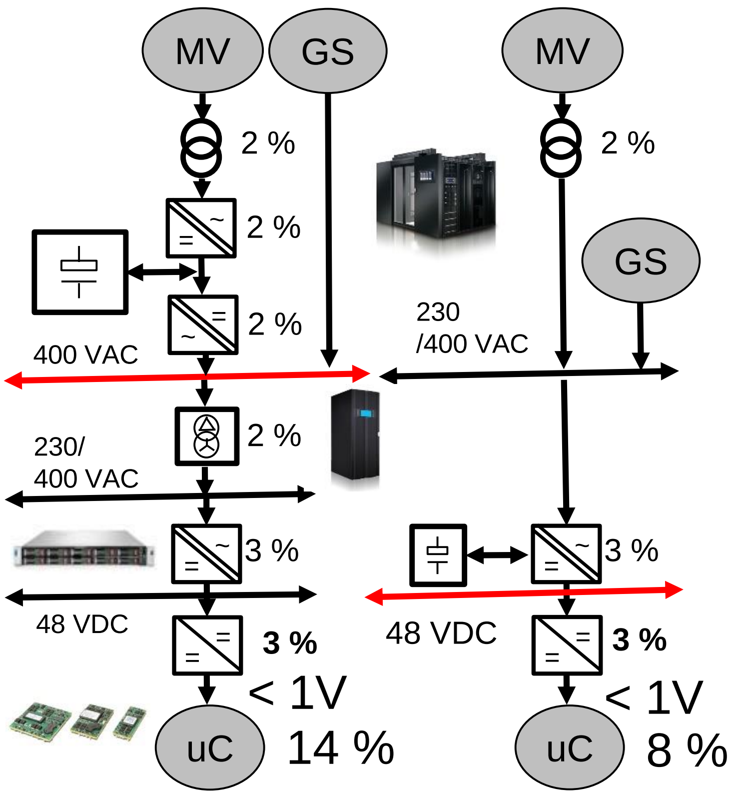




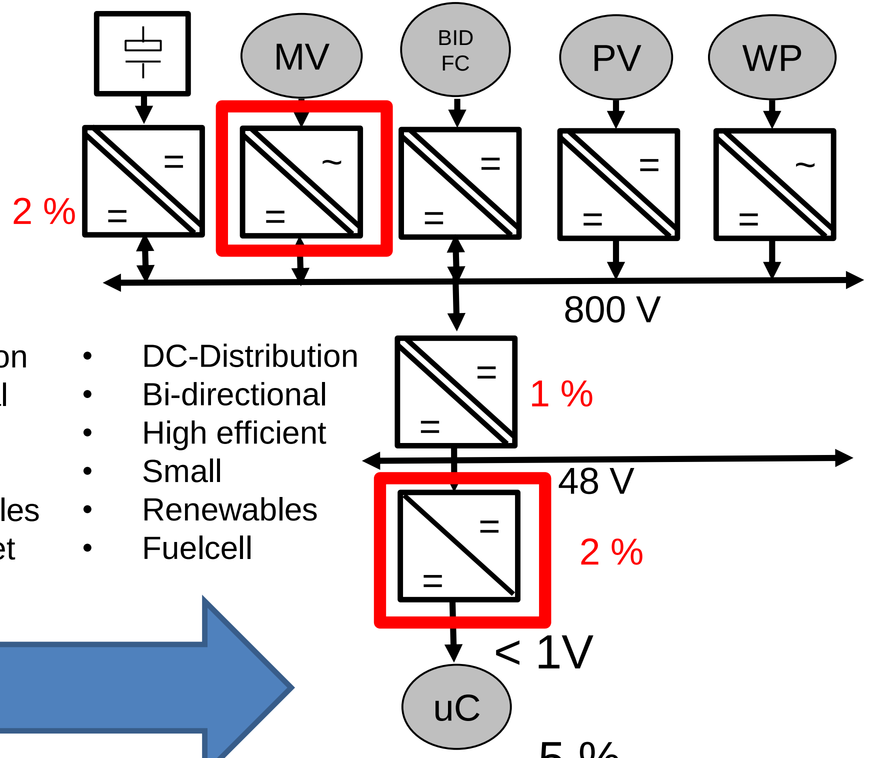
Data Center Power System Technology

Datacenter MV AC-> uC

Today:



Future:



- AC Distribution
- Unidirectional
- Low efficient
- Large
- No Renewables
- Diesel Genset

- DC-Distribution
- Bi-directional
- High efficient
- Small
- Renewables
- Fuelcell

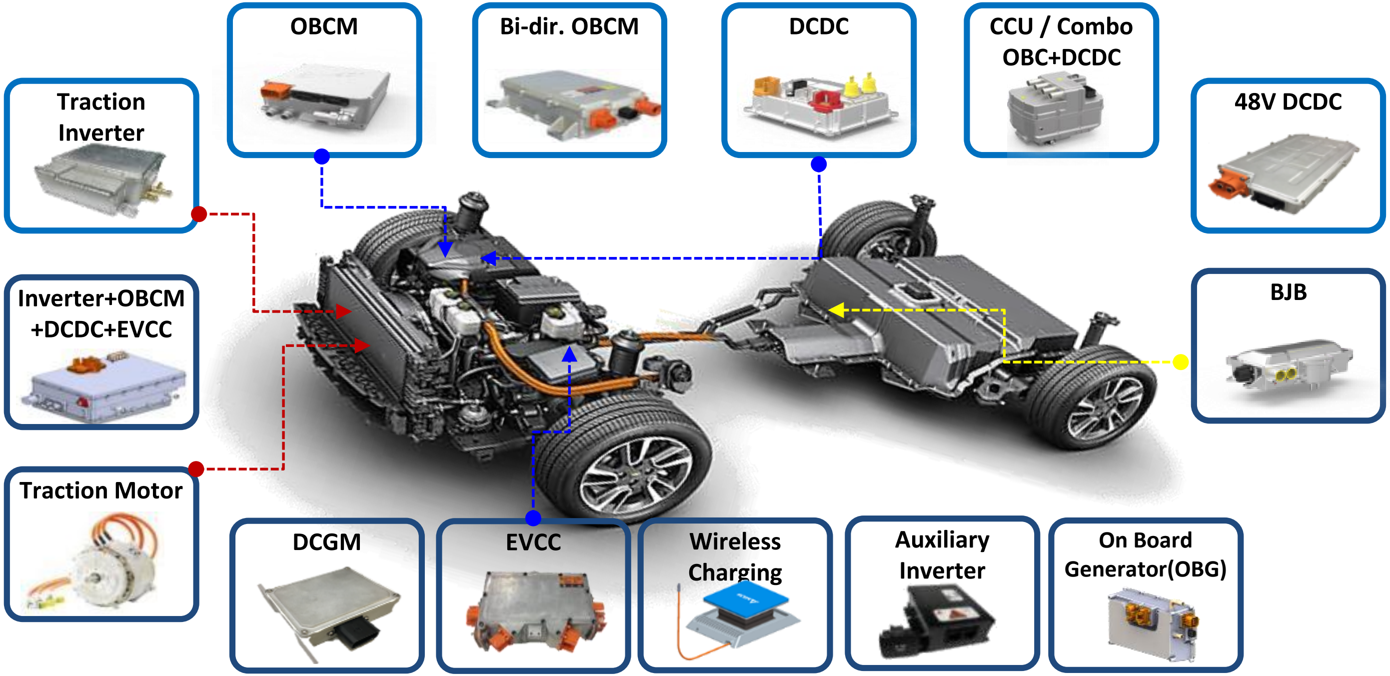
Data Center Power System Technology

Research directions:

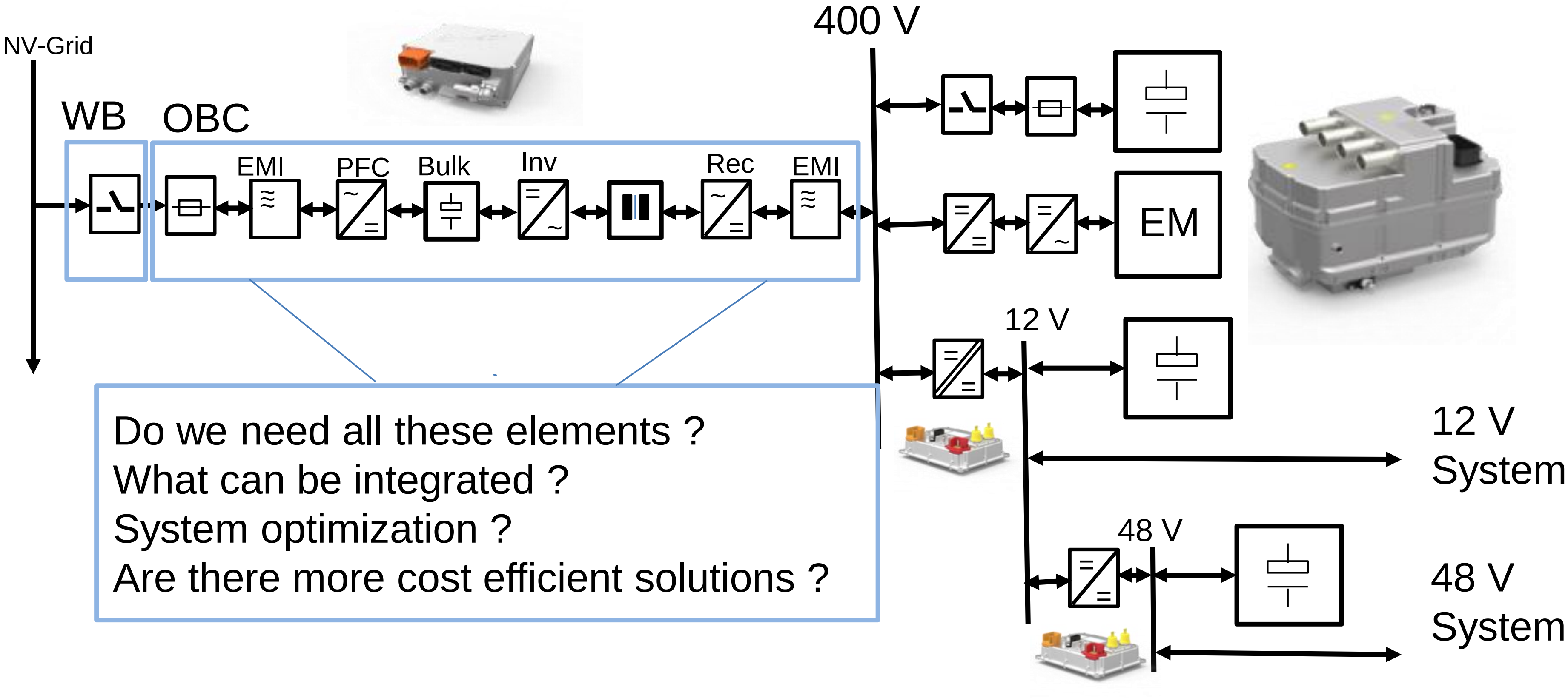
- < 5% loss, Datacenter efficiency and carbon footprint optimization
- < 2 % loss **MV->DC solid state transformer technology**
- < 2% loss POL converter optimization
- Increase of Board supply voltage
- System reliability analysis and optimization
- DC-Distribution Electrical Safety analysis and optimization
- 800 V -> 12V/48V conversion technology
- Renewable integration optimization and power flow
- Total cost of ownership analysis and optimization
- Availability and on-time optimization

EV Power System Technology

Delta custom made products: No System, components



OB EV Power System Technology

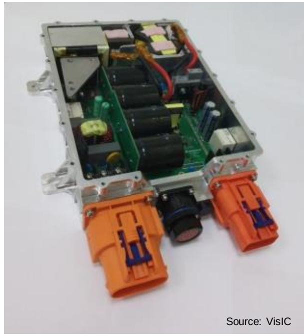


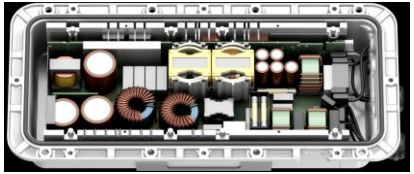
Components and packaging

1/3 Phase AC -> HVDC

Today:

Power density: 33W/in^3 (2 kW/l)
Efficiency:
85% @ 10 % Load
95,5% @ 50 % Load
95,% @100 % Load
Liquid cooled



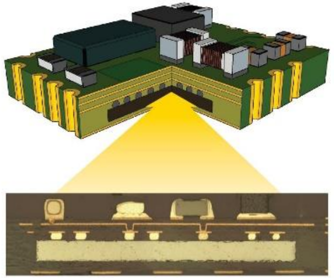


- PCB main component carrier
- Discrete THT and SMT
- Wound magnetics

Future:

Power density: 100 W/in^3 (**6 kW/l**)
Efficiency: >97 % pk@50 % Load

Cermic Module



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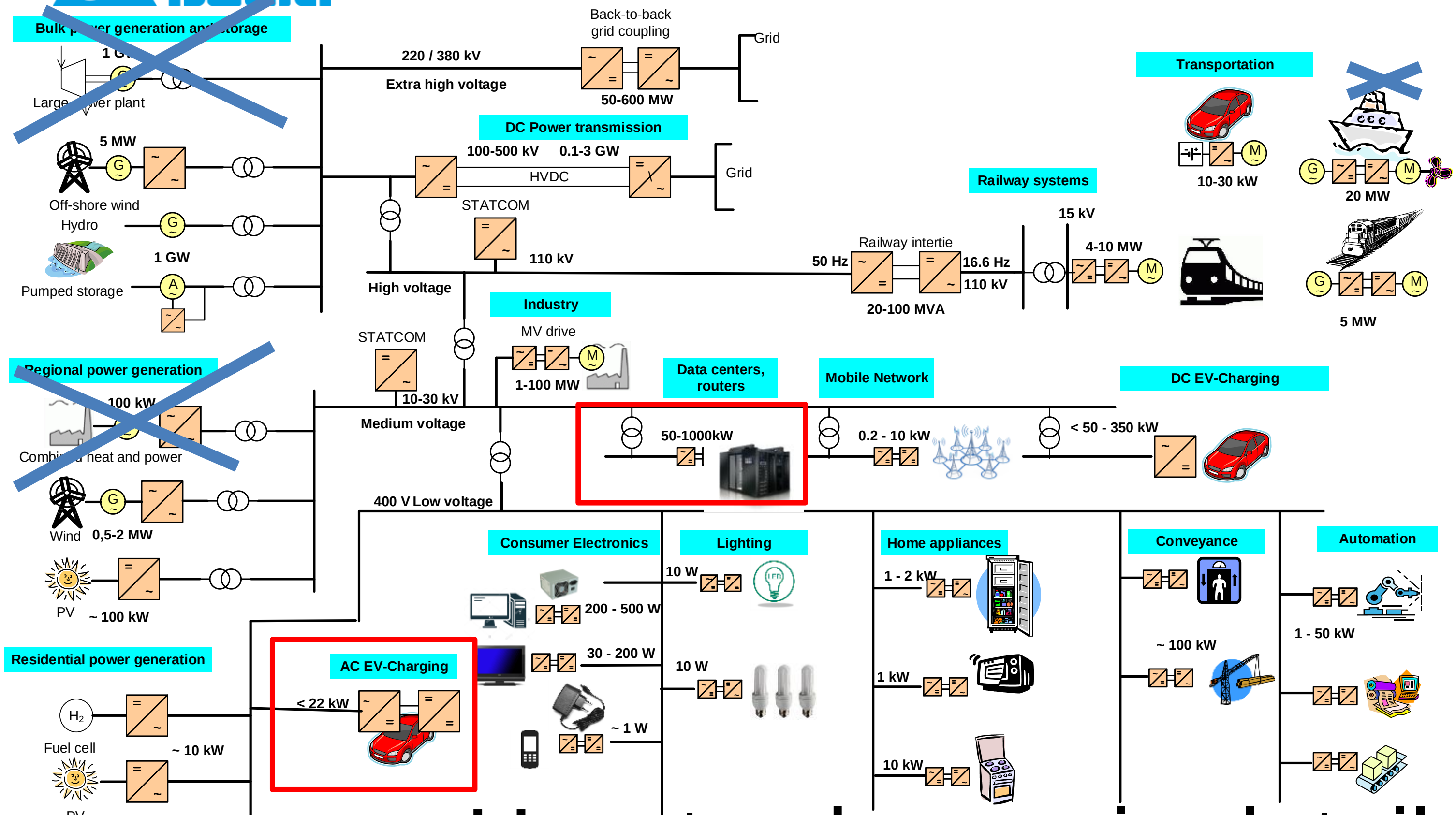
cross-section of embedded module

PCB embedded modules

Needs to be considered in PEDS research in add.

- Reliability / Maintenance
- Endurance / strength
- Electrical diagnostics
- **State of health monitoring (New)**
- Safety relevant requirements / goals
- Electrical and Functional Safety
- System reliability
- Physics of fail
- System integration
- Environmental compatibility

What is PEDS future



Power Electronic Systems
in
- generation,
- distribution,
- utilization

of electrical energy with:

- Renewable
- 0 carbon footprint
- High functionality
- Sustainable
- Bi-directional
- Efficient
- Intelligent
- load source coordination
- Small
- Resilient

How to change in detail ?

Backup

Key Note from Divan 2009

The **fossil fuel** based energy economy that brought us so far is **heading for a transformation**. Higher oil **prices**, increasing **GHG emissions**, and **accelerating climate change** point to the **unsustainability of** the **present course**, and point towards **developing an energy infrastructure** that is **sustainable**.
Possible major **technology shifts** are imminent, including a shift to an **electrified economy**, with **electric vehicles** displacing petroleum fueled cars, and with increased emphasis on **renewable energy** and increased **efficiency.** Power electronics will play a critical role in this transformation – ranging from **sustainable energy sources**, **grid integration**, **smart power delivery**, **load-source coordination**, **energy storage**, **microgrids**, and increased **efficiency of energy** use.
However, the solutions have to be examined from a **systems perspective**, looking at a complete **resource and emissions picture**, and at **sustainability of the solutions on a global basis**.
Further, the **economics of the solution**, not only at the final point, but **along the path**, have to be addressed for success to be achieved. Finally, it is important to understand the **impact of current policies** on technology solutions, and **possible changes in policy** that can be driven by **new technology developments**.

Lorenz 2009

Abstract: The demands on future electric drives will include a significant need for **dynamic efficiency control**, while not compromising **dynamic performance**.
Machine drives that allow **continuous dynamic manipulation of losses** have the potential to become dominant candidates, especially in the rapidly evolving **EV and HEV** applications and more **electric aerospace applications**. For such applications, **dynamically variable loading** with high **peak-to-average torque** and **speed requirements** are typical.
Flux intensifying- and flux weakening-interior permanent magnet (FIIPM & FW-IPM) machines and **induction machines (IM)** are most compatible with these applications since they intrinsically enable **manipulation of flux linkage to dynamically trade off copper, iron, and inverter losses**.
Drive controls need to take advantage of this opportunity. Of the candidate technologies, fixed switching frequency, deadbeat-direct torque and flux control (DBDTFC) is most directly compatible. DB-DTFC uses one control law to handle the full operating space, including voltage limits, allowing simple and robust implementation. The fixed switching frequency also enables the use of zero speed self-sensing methods and dynamic loss minimizing control. This technology appears to have the potential to become the dominant control methodology for future motor drives.

Smarter. Greener. Together.

To learn more about Delta, please visit
www.deltaenergysystems.com.