AICQ 2023 – ALESSANDRO PALMIERI – POWER ELECTRONICS ENGINEERING MANAGER - ITALY

Innovations in the market for auxiliary converters and battery chargers

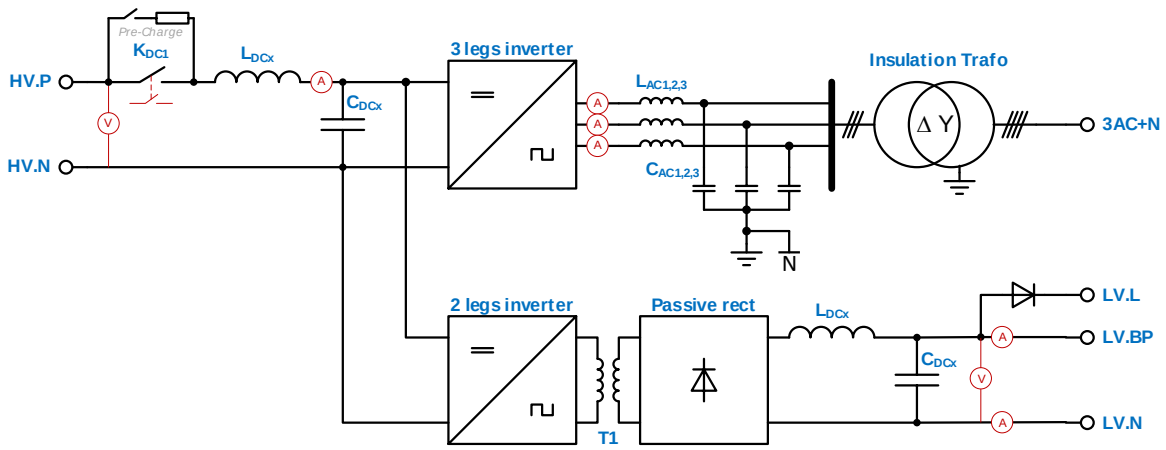
How new technologies and new strategies enable a lightweight and efficient design

New Auxiliary Converter concept in a nutshell

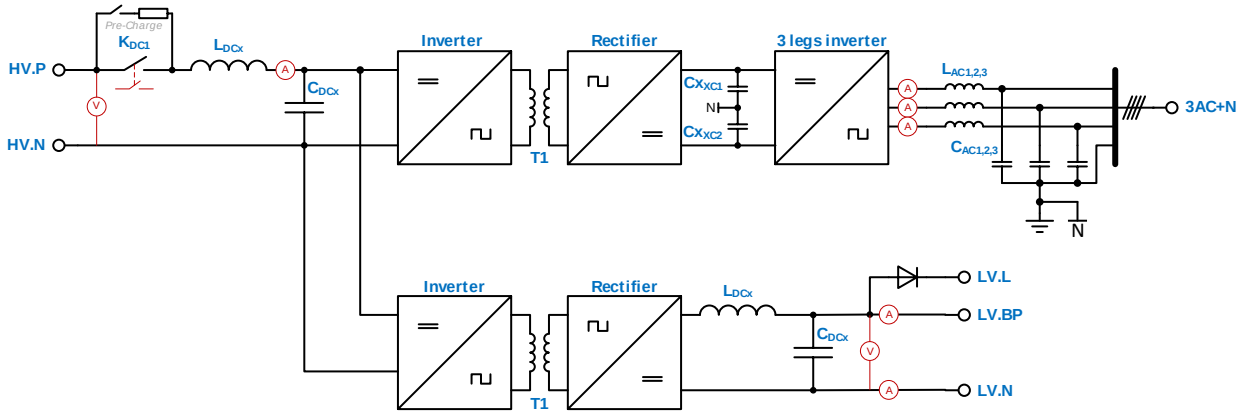
Auxiliary converter and battery chargers

Low vs Medium frequency topologies

Low frequency



Medium frequency



New generation of auxiliary converter

Strategies for a more compact and lightweight converter

Technology leap

Wide Bandgap Semiconductors

- Higher voltages
- Higher temperatures
- Higher frequency

Silicon Carbide (SiC) chipset

Gallium Nitride (GaN) chipset

Power electronics topologies

Soft switching topologies and modulation schemes

- Series resonant converter
- Dual active bridge

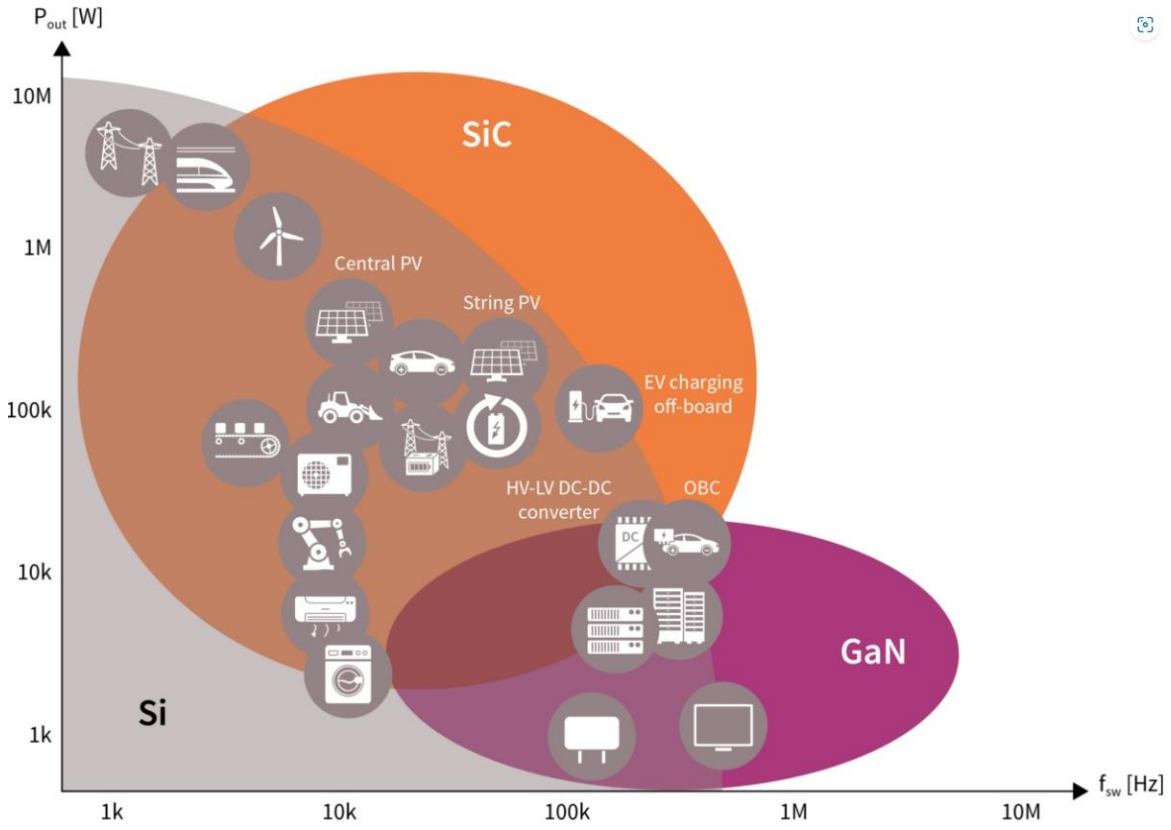
Multilevel topologies

- Modular multilevel converter (MMC)
- Flying capacitor multilevel converter

Introduction to Wide Bandgap Semiconductors

Power Semiconductor devices

Frequencies and power



Silicon Carbide (SiC) chipset

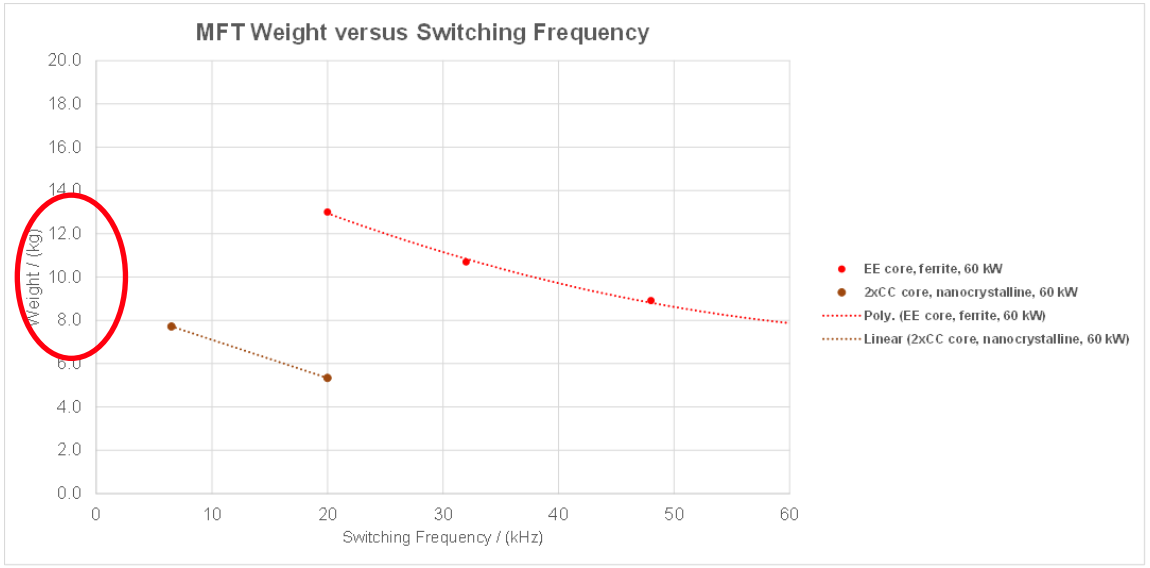
Vertical transistor → Medium/high voltage and power devices

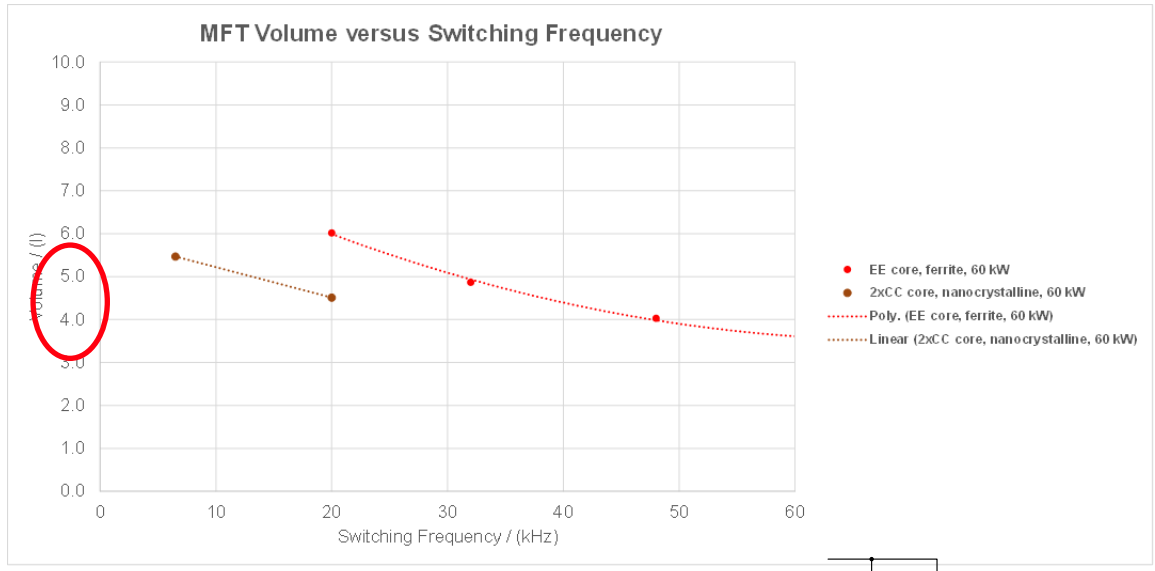
Gallium Nitride (GaN) chipset

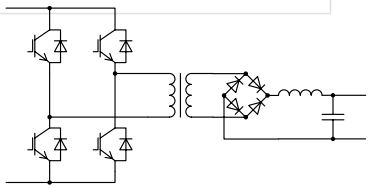
Lateral transistor → Low voltage and power devices

Scaling of Passives (1)

Example for MFT Weight and Volume versus Switching Frequency for a Ferrite and Nanocrystalline Design for 60 kW DC/DC



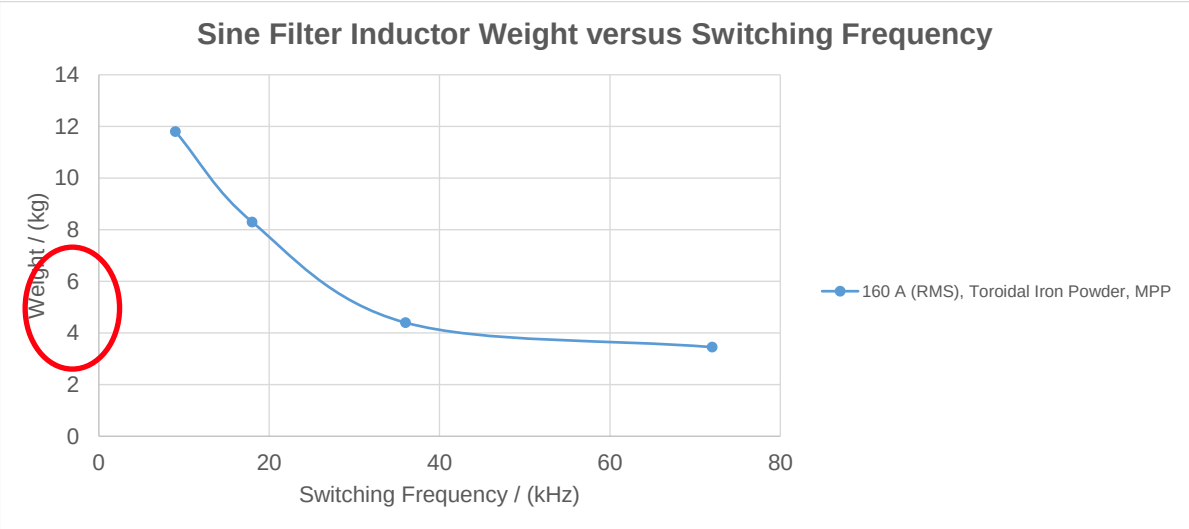


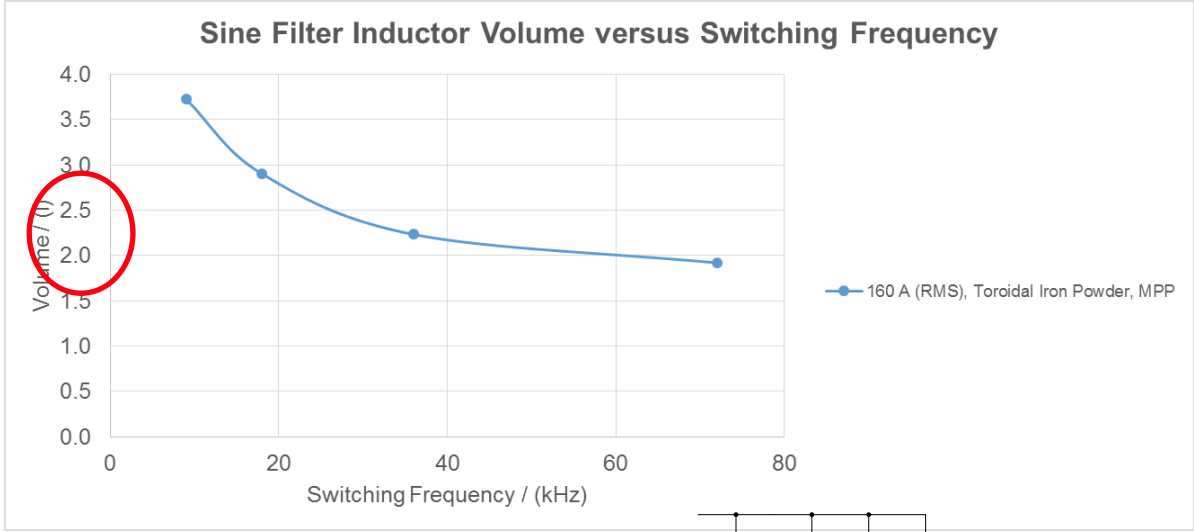


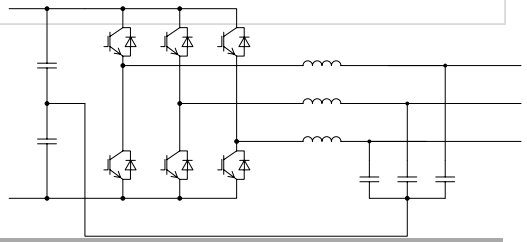
Switching frequencies above 50 kHz are required to achieve considerable gain in weight/volume with lower cost ferrite core based MFTs compared with more expensive nanocrystalline core based MFTs operating between 5 … 10 kHz.

Scaling of Passives (2)

Example for 160 A (RMS) Sine Filter Inductor Weight and Volume vs. Switching Frequency



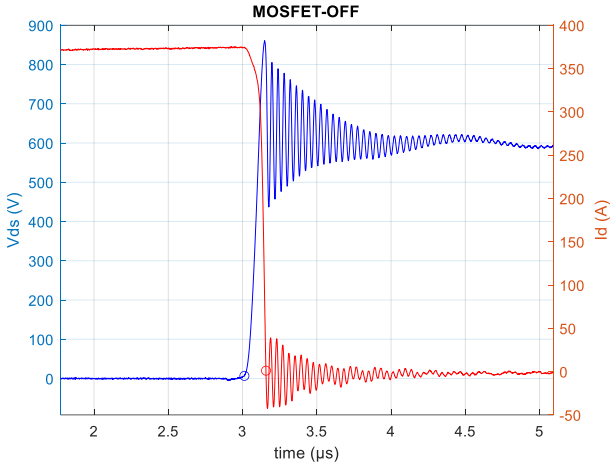




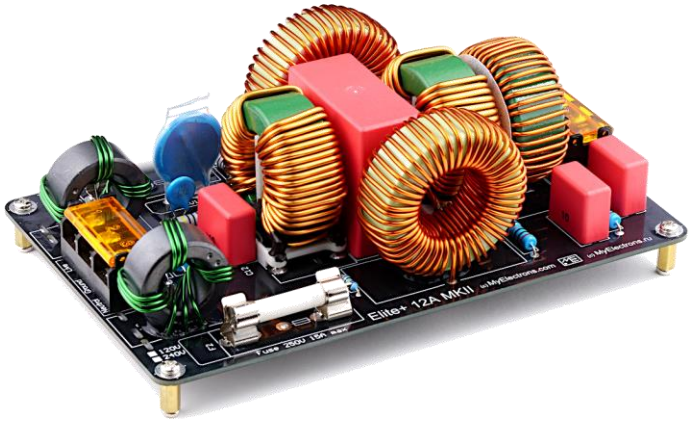
Most of the absolute gain in terms of weight/volume with respect to the total converter weight is achieved by increasing the switching up to 20 kHz.

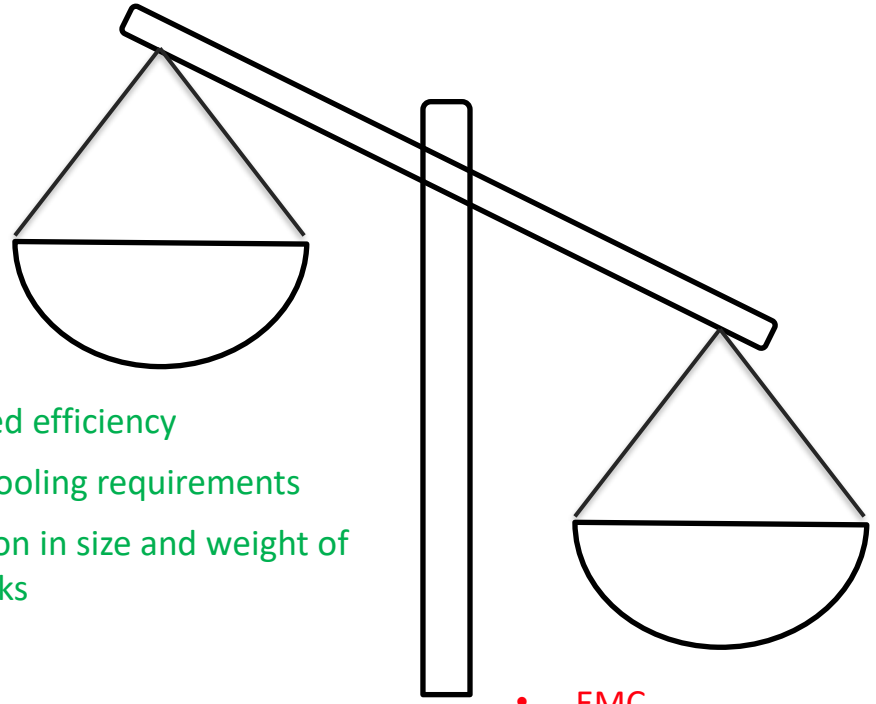
Power Semiconductor devices

Pros&Cons of new wide bandgap devices



- Reduction of switching losses
- Increased switching frequencies
- Switching speed
- New technology





- Increased efficiency
- Lower cooling requirements
- Reduction in size and weight of heat sinks

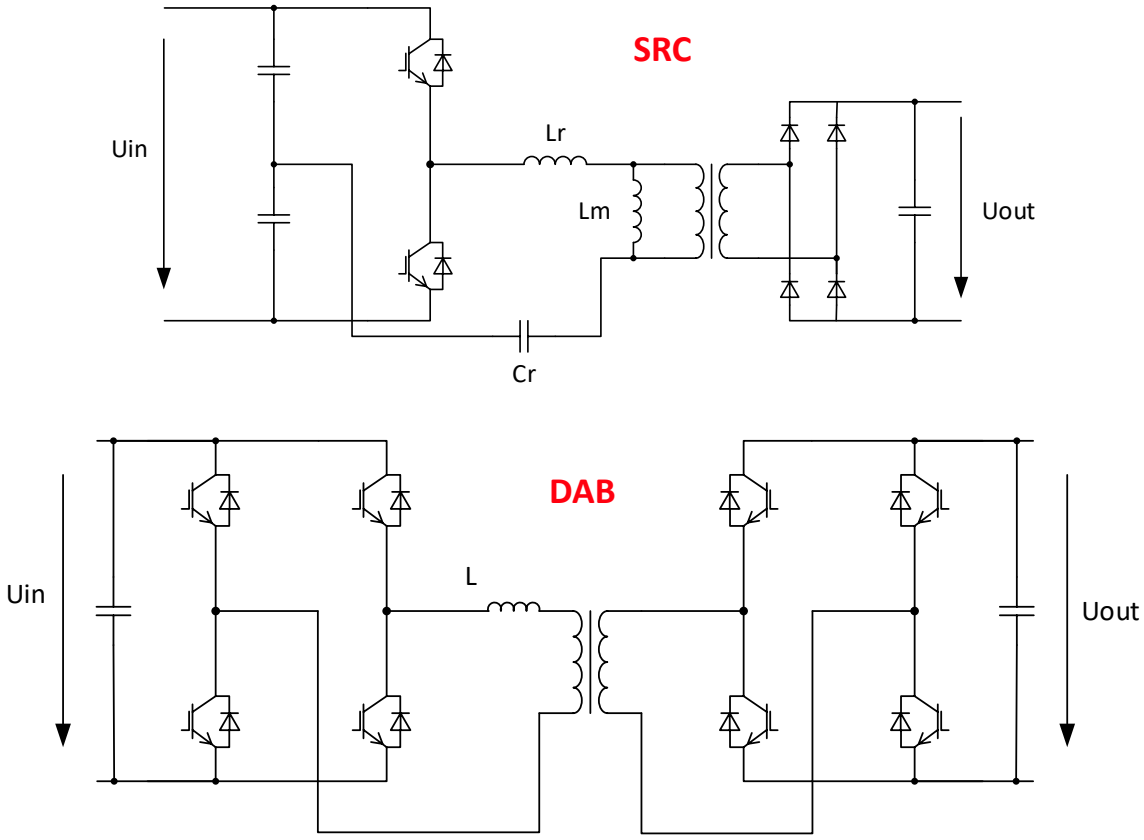
- EMC
- Critical issues in piloting and filtering
- More complex layout
- Cost (especially for SiC)

Multilevel topologies & Soft switching strategies

Soft switching strategies

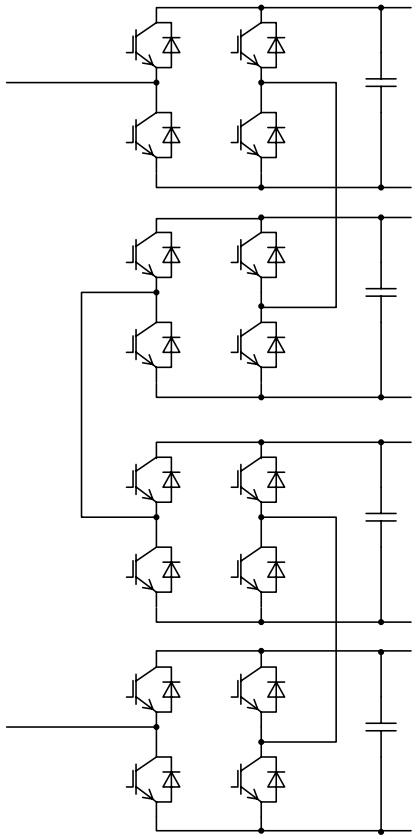
Reduced switching losses obtained by the combination of:

- **Power electronics topologies**
  - Series resonant converter (SRC)
  - Dual active bridge (DAB)
- **Modulation schemes**
  - Zero current transition (ZCT)
  - Zero voltage transition (ZVT)



Multilevel power electronics topologies

Soft switching strategies



Most used multilevel topologies

- Modular multilevel converter (MMC)
- Cascaded H-bridge converter
- Flying capacitor converter
- Neutral point clamped converter (NPC)

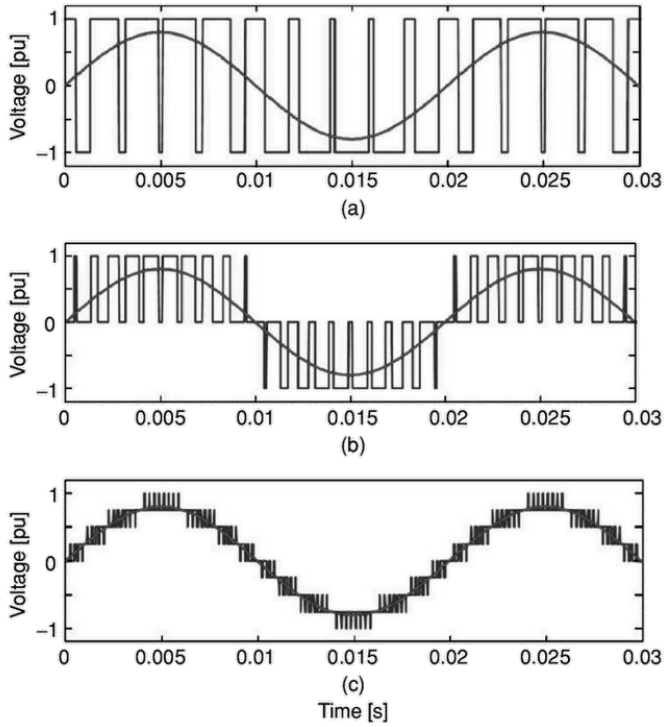
Advantages

- Usage of low voltage more performant semiconductors
- Better voltage and current waveforms
- Degraded mode of operation in view of single fault

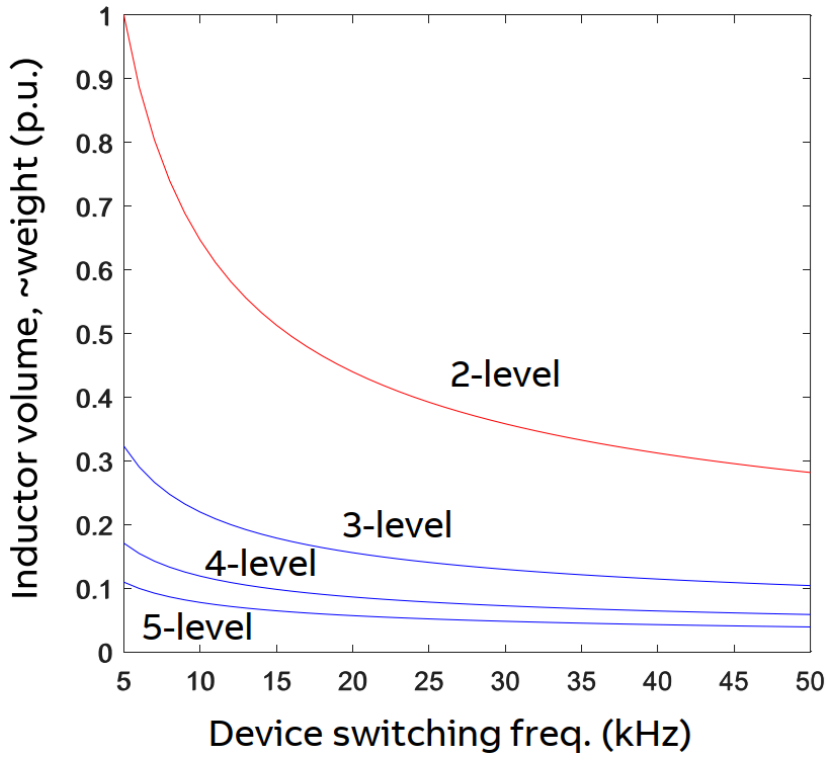
Multilevel topology

Scaling of passives

Comparison: two-level - three-level - nine-level



Impact of switching frequency and number of levels



The impact of SiC on the auxiliary converter

BORDLINE® M35

	Old	New	Difference
Weight	250kg	155kg	-38%
Volume	0,54m3	0,3m3	-43%
Power	32kVA+7kW	35kVA+8kW	+12%

BORDLINE® M55

	Old	New	Difference
kW/m3	93	190	+106%
kW/kg	0,2	0,33	+64%
Power	55kVA+10kW	55kVA+12kW	+4%

BORDLINE® M90

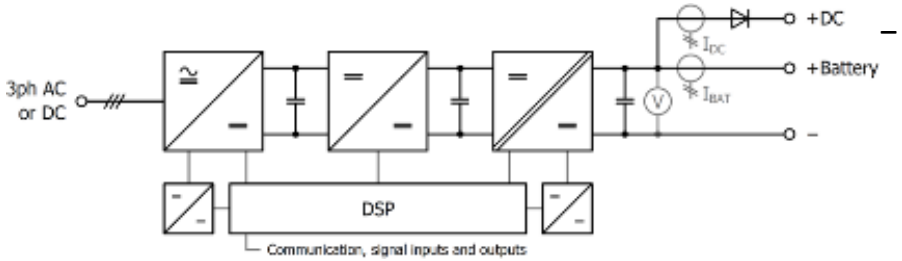
	Old	New	Difference
kW/m3	51	175	+151%
kW/kg	0,15	0,31	+114%
Power	90kVA+16kW	100kVA+20kW	+14%

New compact battery charger for rackmount

BORDLINE® BC - Silicon Carbide Technology

Main Data

- Input Voltage: 400V_{AC} 50Hz 3ph, 480V_{AC} 60Hz 3ph, 650V_{DC}
- Output power:
  - ❑ 10KW @110V_{DC} and @36V_{DC} – **95%->97% Efficiency**
  - ❑ 6,5KW@72VDC and @24VDC – **93%->95% Efficiency**
- Weight: **10kg**

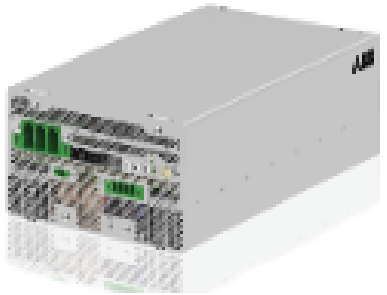


Characteristics

- 3U high 19’ Rack
- Forced air cooling (fans on back)
- Embedded control DSP
- Up to 4 units can work in parallel - Master/Slave (RS485 Bus) or Droop configuration for battery current sharing
- It’s fed directly by the input voltage (control voltage in not needed)
- PTE/TCMS through CANopen connection
- Suitable for most common battery types

Customer Benefits

- Excellent ratio between dimensions, weight and power output
- Modular solution for an easy maintenance
- High reliability
- Energy Saving **(low losses and weight)**



Energy efficiency

How much efficiency impacts environment the fleet of 100 LRVs

Results in energy savings of:

- 14640 tons of CO2
- 70471 of trees
- 98% of the total actual trees in Florence (Italy)

Contact

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Q&A session