Power Electronic Concepts for Auxiliary Power Converter on Rolling stock

International Power Conversion and Drive Conference

- October 16, 2013 in Moscow -

SMA Railway Technology GmbH – Roman Heinrich

SMA Railway Technology GmbH

- Former Railway Technology Business Unit of SMA Technologie AG with more than 25 years of experience
- Since June 2008 separated legal entity
- Wholly owned subsidiary of SMA Solar Technology AG

SOLAR TECHNOLOGY

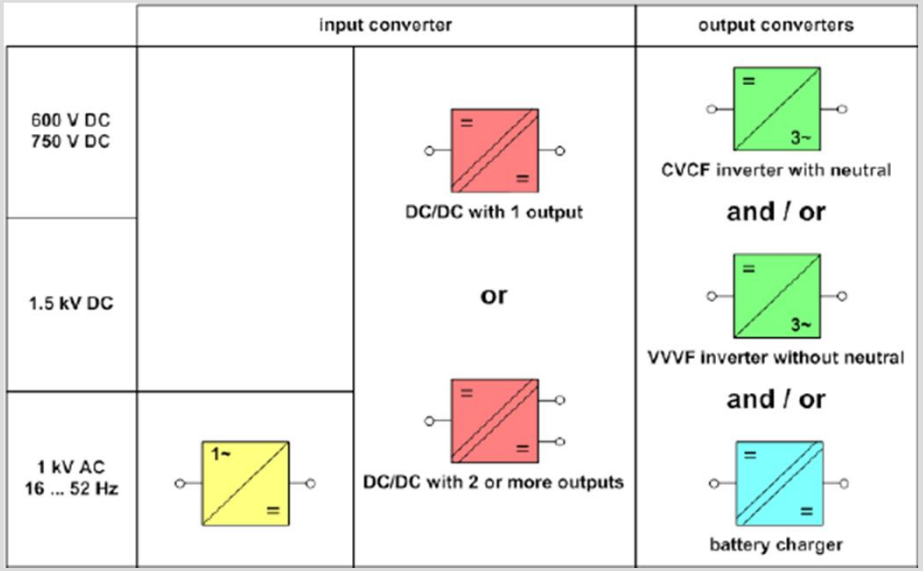
RAILWAY TECHNOLOGY

- Employees: 235 (2009), 265 (2010)
- Turn-over: € 30 Mio. (2009), € 40 Mio. (2010)

Overview of topics

- Requirements for modern train concepts and electrical equipment at the train
- Topology of „SMARTconverter 2nd generation“ APC for 750 V DC railway catenary
- Topology of „SMARTconverter 2nd generation“ APC for 1.5 kV DC railway catenary
- Topology of an auxiliary power converter for 3 kV DC catenary by using 6.5 kV IGBTs
- Protection measures and handling of critical boundary conditions
- Standard topology of auxiliary power converters for 15 kV 16.7 Hz AC catenary
- SMA topology proposal for auxiliary power converter for 15 kV 16.7 Hz AC catenary and experimental results

Requirements for modern train concepts and equipment at the train



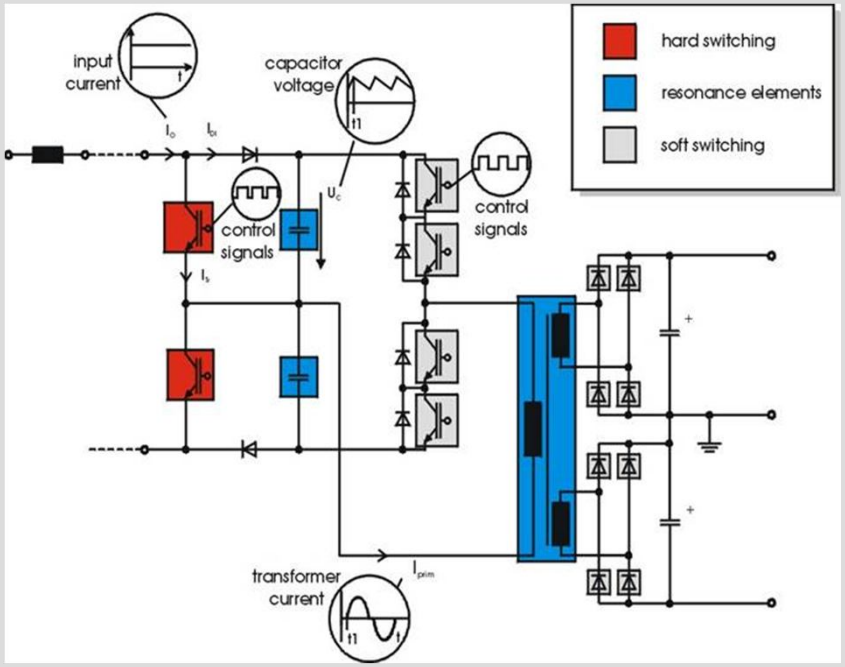
Requirements

- > Increasing power demand
- > Reliability
- > Ruggedness
- > Weight
- > Costs

Applications

- > Input voltages: 750 VDC, 1.5 kV DC, 3 kV DC, 15 kV AC 16.7Hz, 25 kV AC
- > Output voltages: 24 V DC, 72 V DC, 110 V DC, 208 V AC 60 Hz, 380 V AC 60 Hz, 400 V AC 50 Hz, variable AC voltage
- > Power: 50 kW – 240 kW

Basic topology of the DC/DC converter

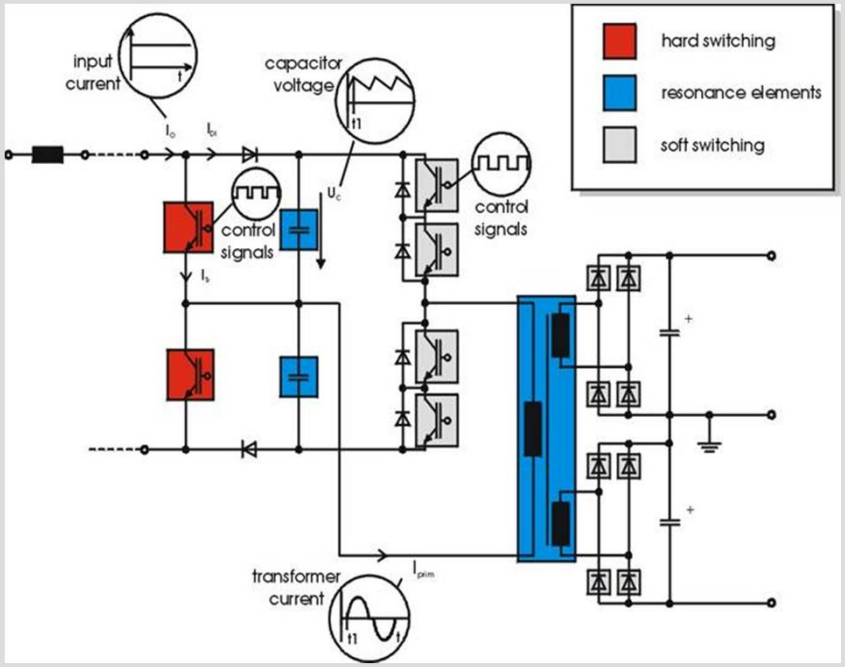


> Galvanic isolated DC/DC converter with two DC outputs

  > DC output to supply the train loads 110 V DC

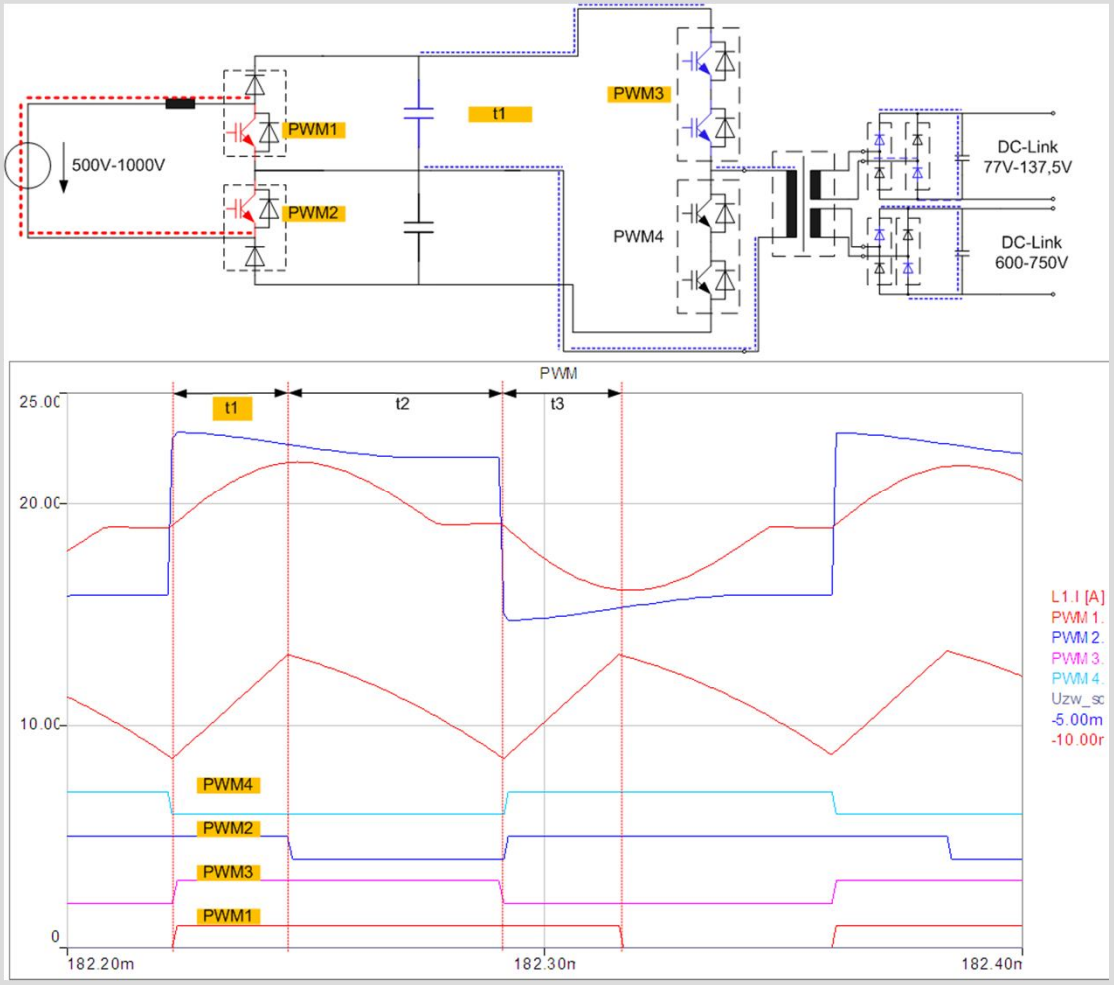
  > DC link for three-phase inverter

Basic topology of the DC/DC converter

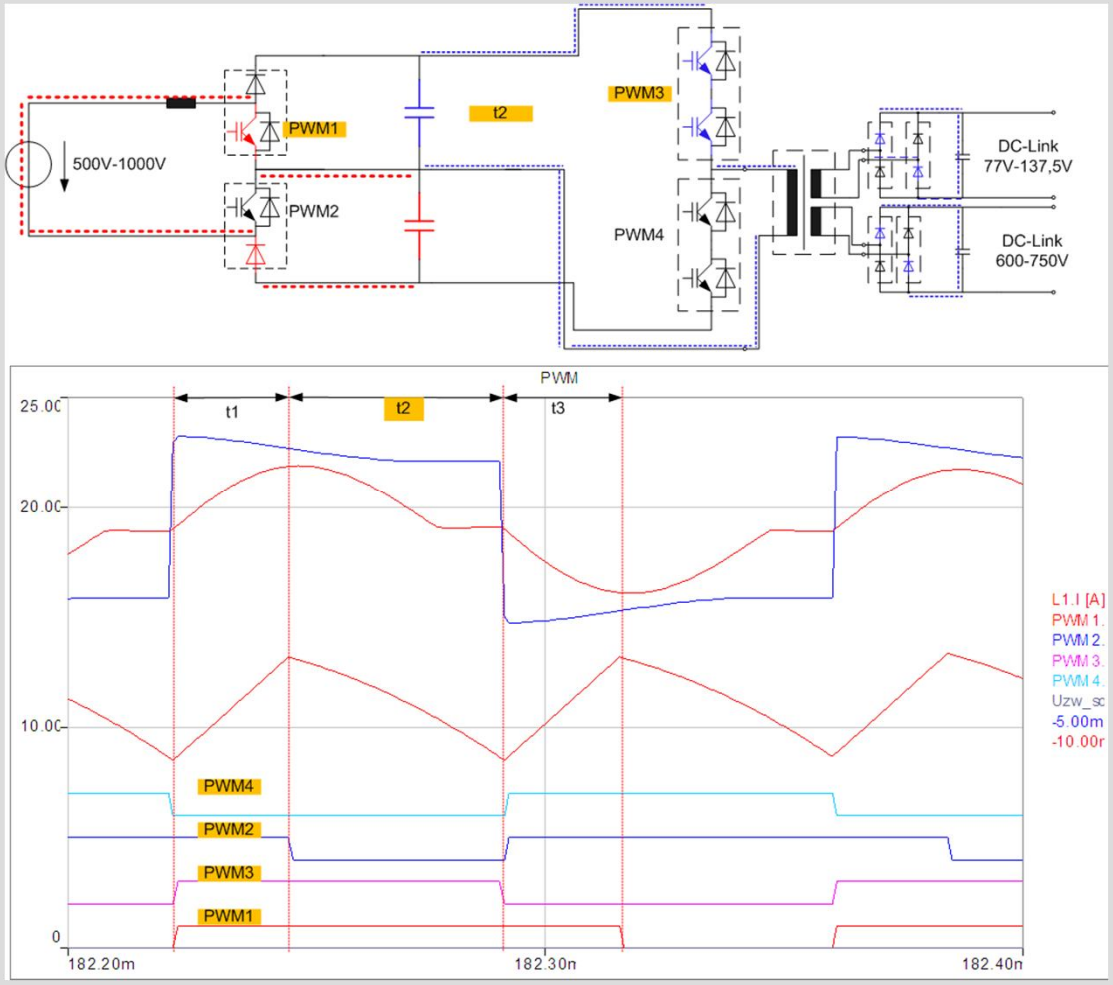


- Consist of:
  - Boost converter choke
  - Boost converter
  - DC/AC inverter
  - Transformer with two secondary windings
  - Two rectifiers

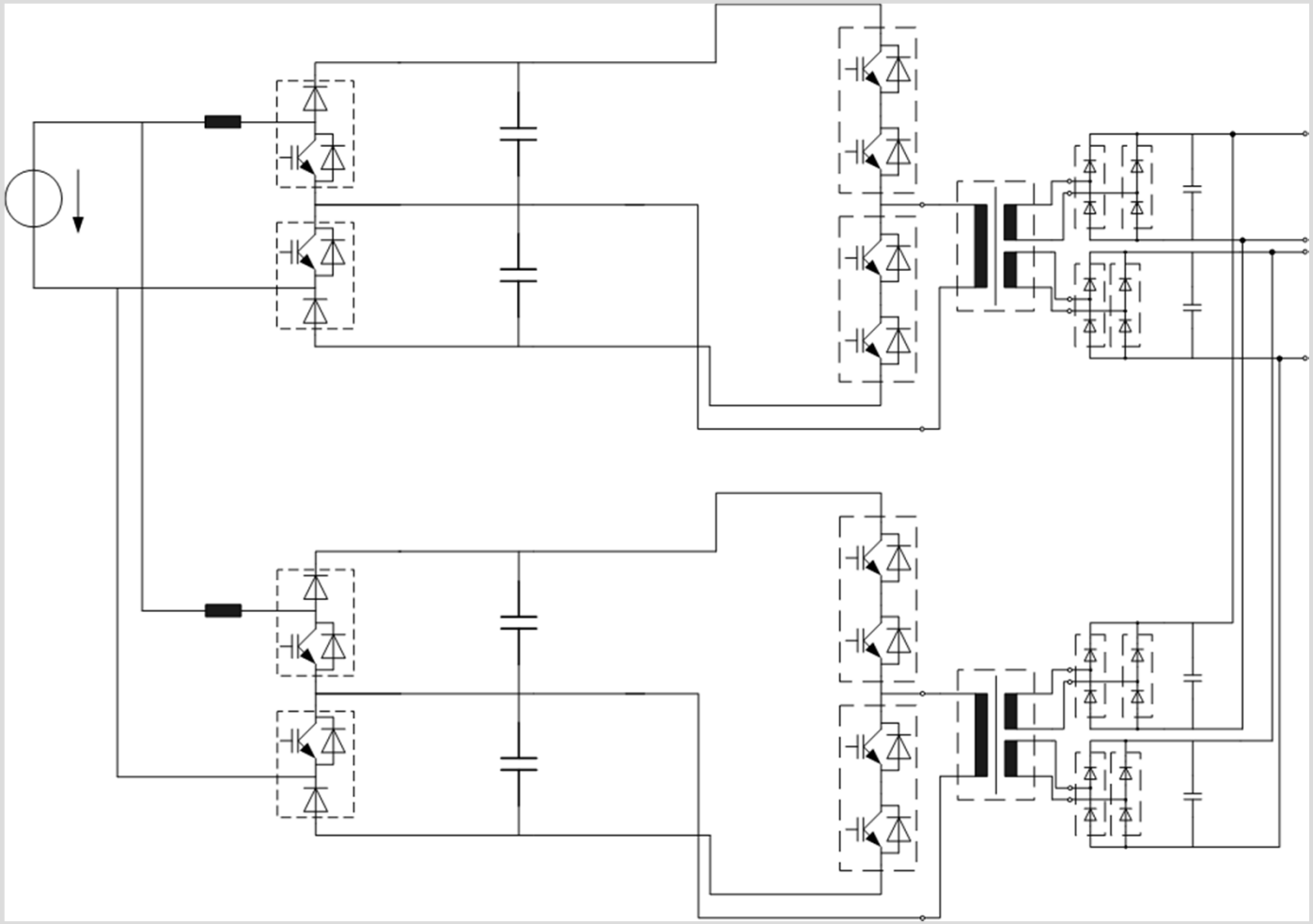
Basic topology of the DC/DC converter



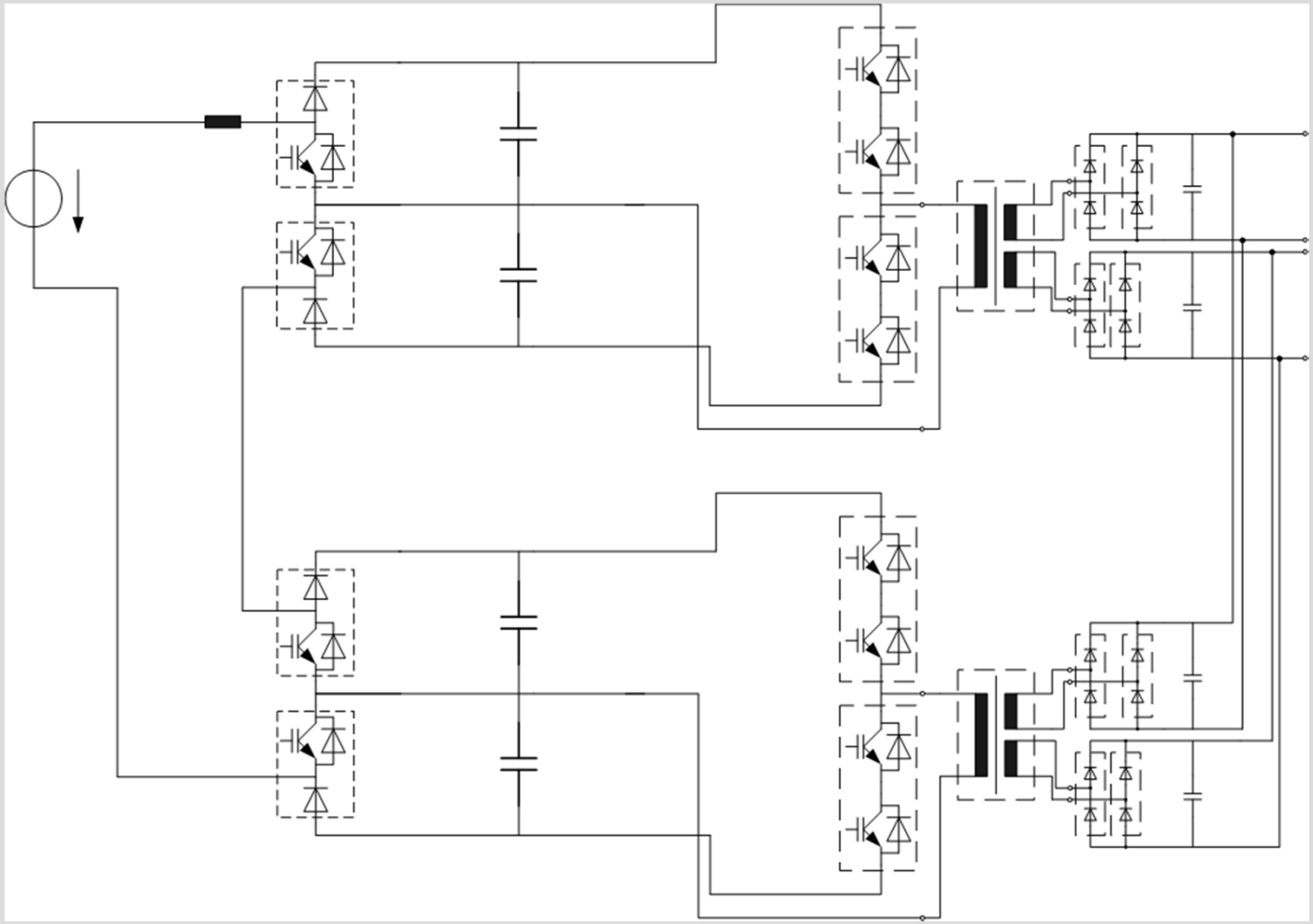
Basic topology of the DC/DC converter



Parallel connection of the DC/DC converter modules



Serial connection of the DC/DC converter modules



Serial connection: advantages

Advantages

> Voltage is shared equally between modules.

> Possible to use 1.2 kV IGBT-modules

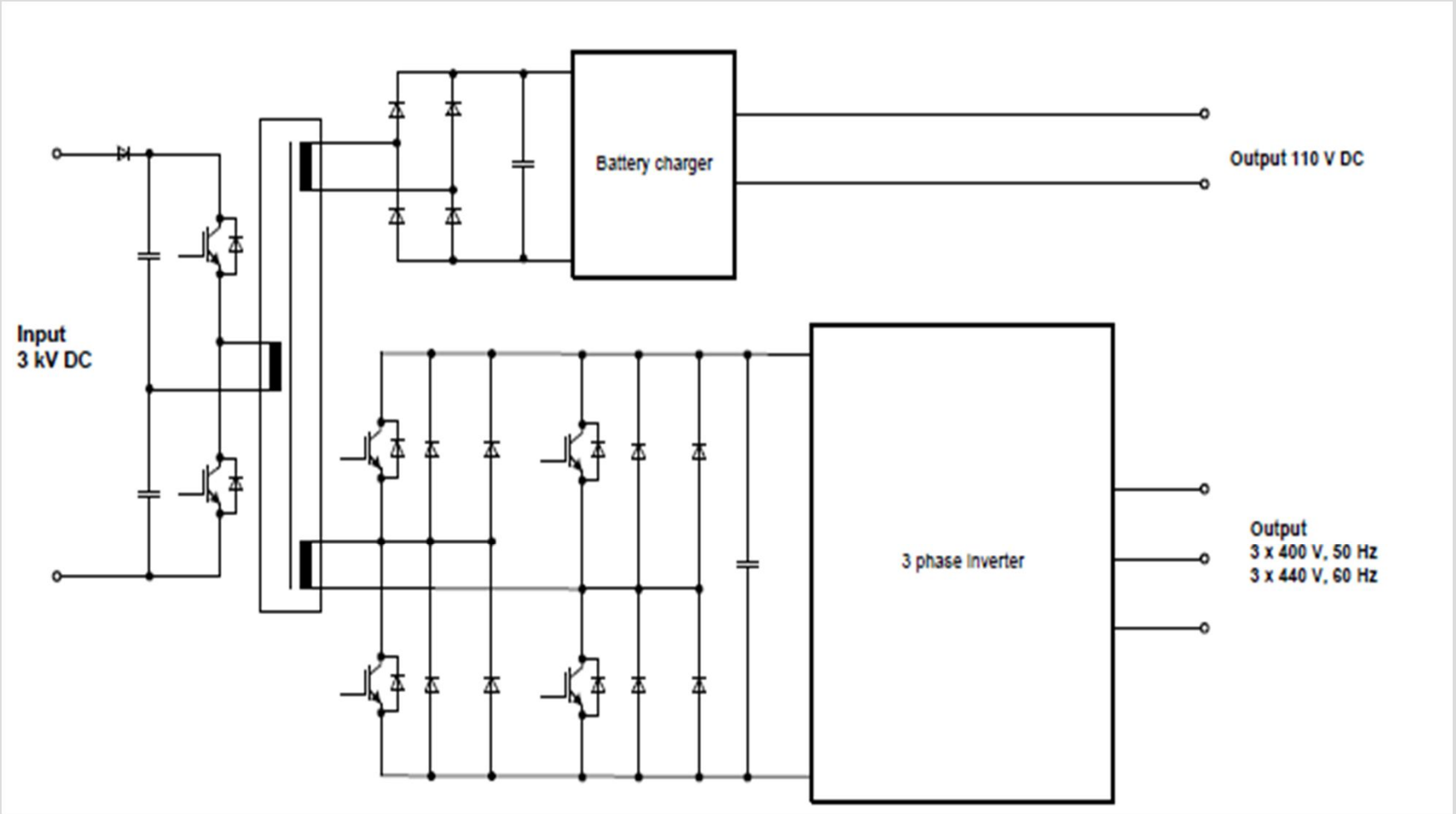
> Higher switching frequencies are possible (up to 8 kHz).

> Interleaved switching method is possible.

> Lower current ripple at the input

> Lower current ripple through the filter capacitors at output

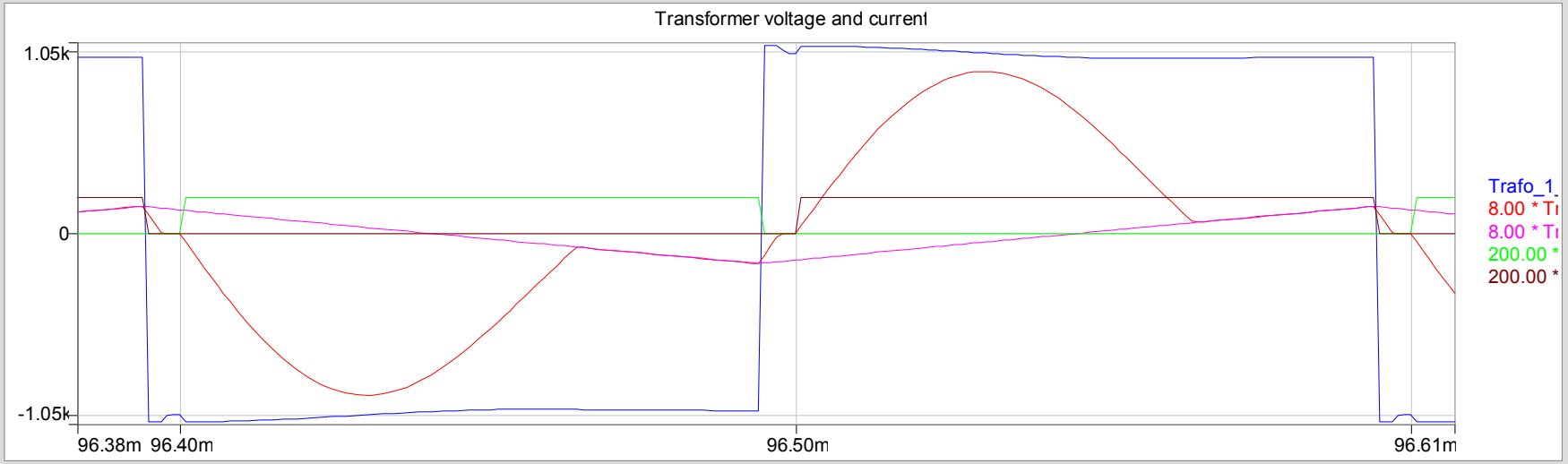
DC/DC converter for 3 kV DC catenary



DC/DC converter for 3 kV DC catenary

- To be considered:
  - Commutation process of 6.5 kV IGBTs in resonant switching application
    - Clearing time of residual carrier charge of approx. 50 µs
    - Interlock time between IGBT pulses has to be set to 50 µs.
    - Reduction of interlock time is possible by applying external circuits or using the magnetizing current of the transformer.
    - Reduction of the interlock time is possible by modulation of the IGBT conductivity during the conduction phase.
    - Not considering of this effect leads to increase of the switching losses.

DC/DC converter for 3 kV DC catenary



> Blue: Voltage at the primary side of the transformer

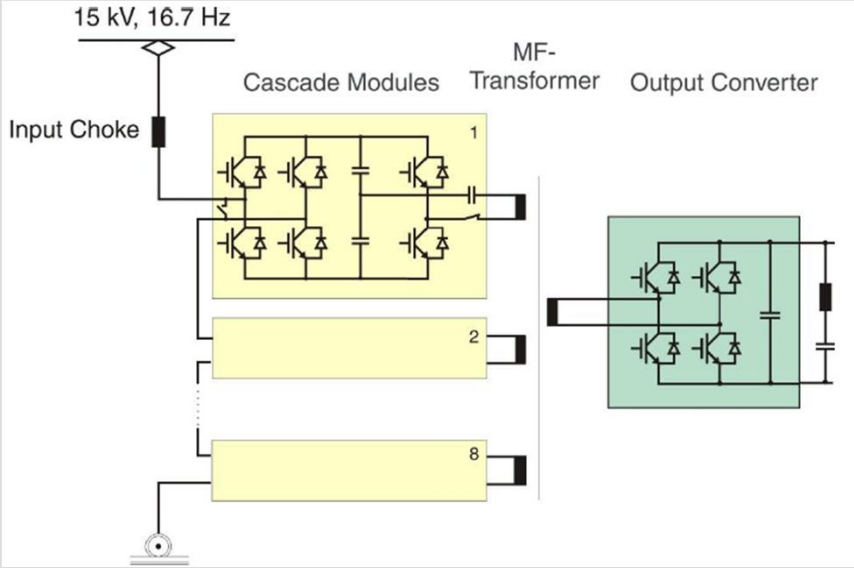
> Red: Current trough the primary winding of the transformer

> Purple: Magnetizing current flowing through the main inductance

DC/DC converter for 3 kV DC catenary

- To be considered:
  - No resonant switching during start-up or cut off of the IGBT switching
  - Short circuit at the secondary side of the transformer
    - Limited only by the resonant circuit
  - Ripple current at the input

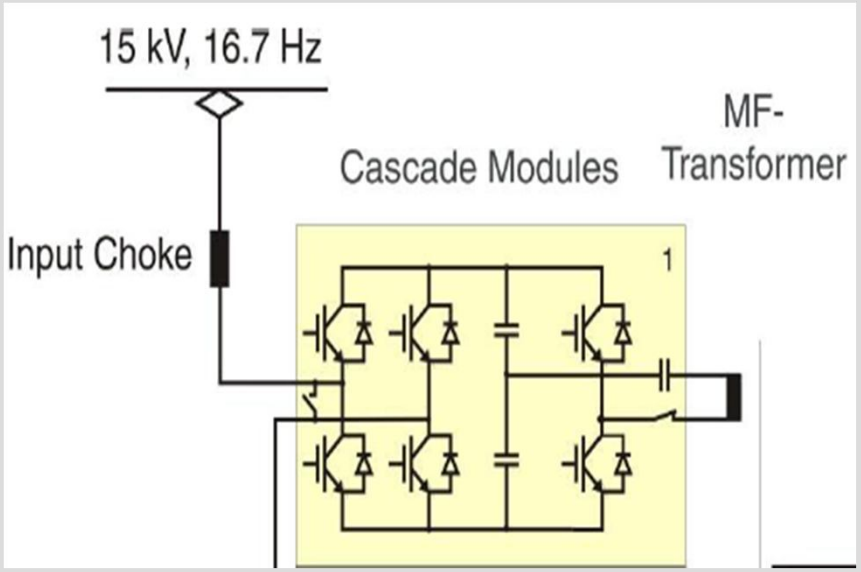
AC/DC converter for 15 kV AC 16.7 Hz



- Eight cascade modules connected in series and switched with interleaved method.
- Input choke
- Transformer with eight secondary windings and one primary winding
- One rectifier at the secondary side with an 1.65 kV DC link and 33.3 Hz filter circuit

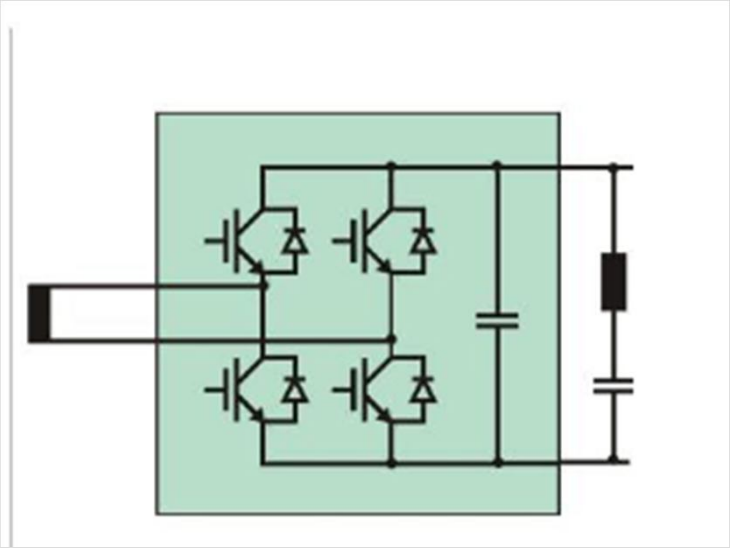
AC/DC converter for 15 kV AC 16.7 Hz

- Cascade module consist of :
  - Full-bridge switched with 1 kHz
  - Controlled DC link (3.6 kV)
  - Resonant DC/DC converter switched with 5 kHz connected via a resonance capacitor to one of the primary windings.



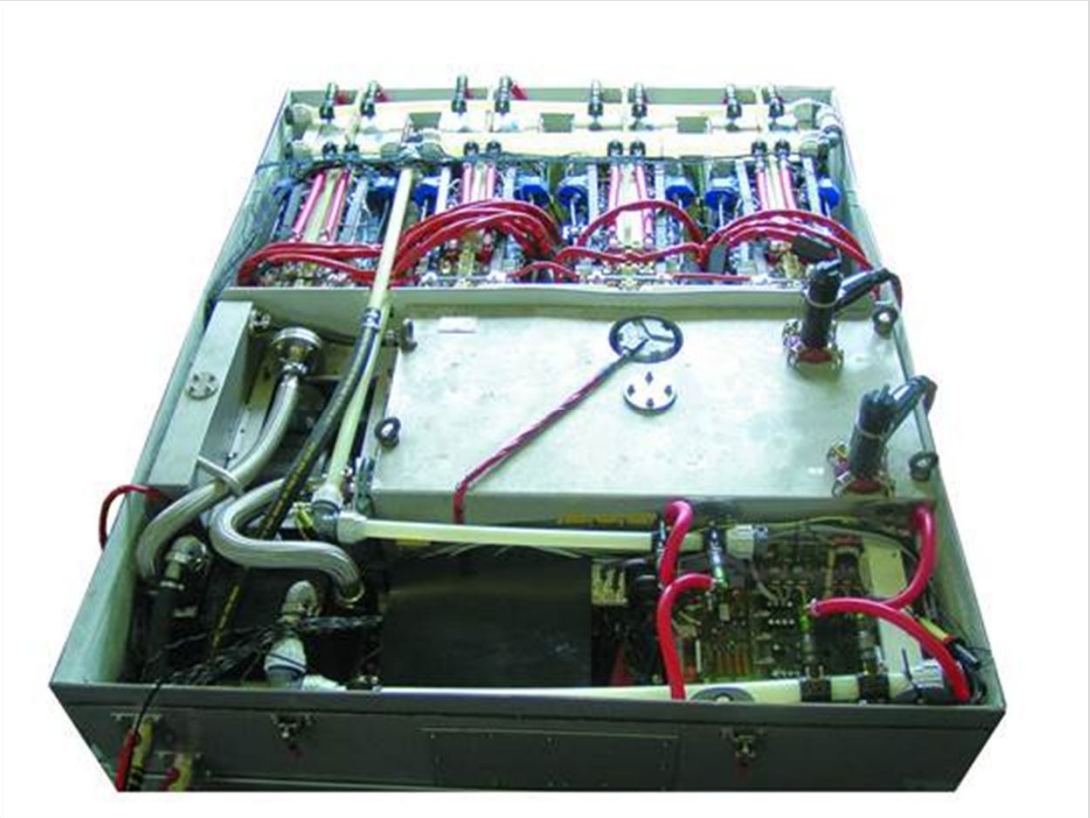
AC/DC converter for 15 kV AC 16.7 Hz

- Output converter consist of :
  - Full-bridge used as a passive rectifier in consumer mode and as a active converter in feedback mode
  - DC link with a capacitance of several mF
  - Filter circuit designed for resonance frequency of 33 Hz



AC/DC converter for 15 kV AC 16.7 Hz

Main data of realized system



AC/DC converter for 15 kV AC 16.7 Hz

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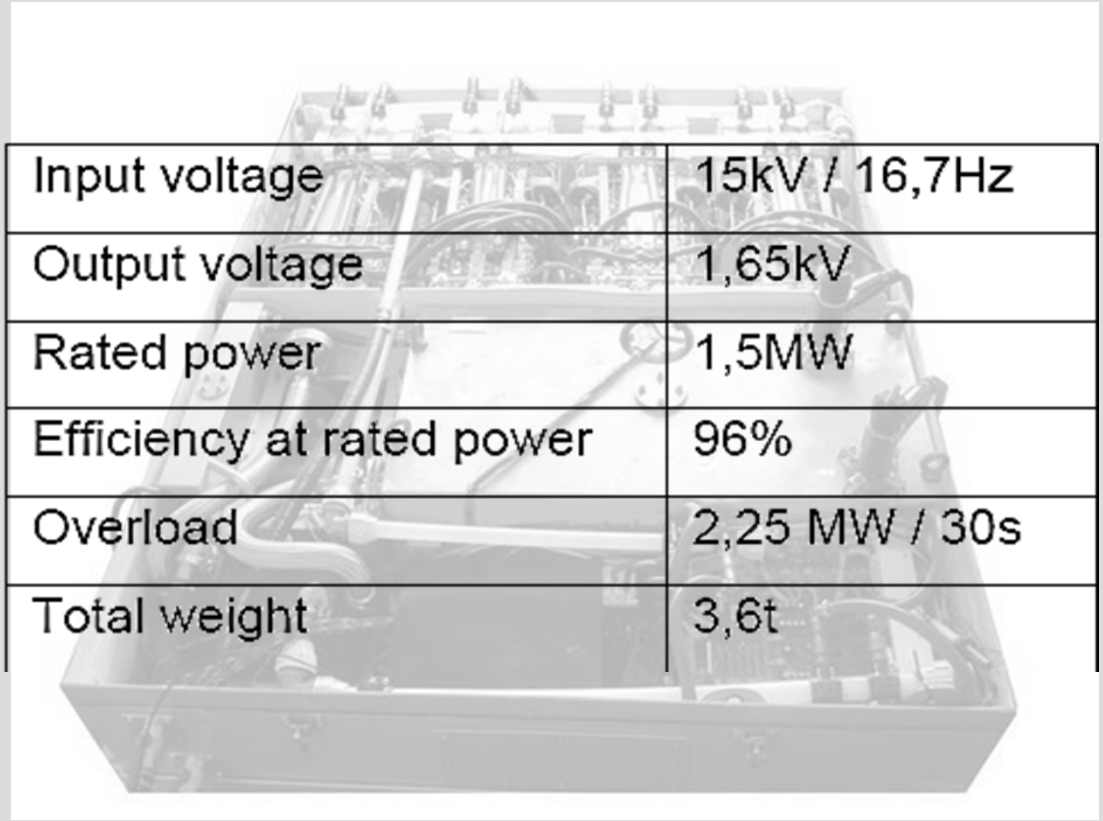

Input voltage	15kV / 16,7Hz
Output voltage	1,65kV
Rated power	1,5MW
Efficiency at rated power	96%
Overload	2,25 MW / 30s
Total weight	3,6t

AC/DC converter for 15 kV AC 16.7 Hz

Power dissipation

Primary input converter	23 kW	470 W per hard switching IGBT of 4-Q-Converter 500 W per resonant switching IGBT
Secondary resonant converter	8 kW	
MF transformer	15 kW	Efficiency of 99 %
Input choke	10 kW	
2-f filter	2 kW	
Other components	2kW	

Train application

> Lirex experimental

Summary

- A family of power electronic topologies for a power range from several kW to 1.5 MW has been presented.
- The modular approach allows to cover an input voltage range from 750 V DC to 15 kV AC.
- Sophisticated power electronic technologies determine the life cycle costs of the rolling stock applications.

Thank you for your attention!

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