Railenergy

Energy Efficiency Days 2009

Panel 5 – Innovative Traction systems

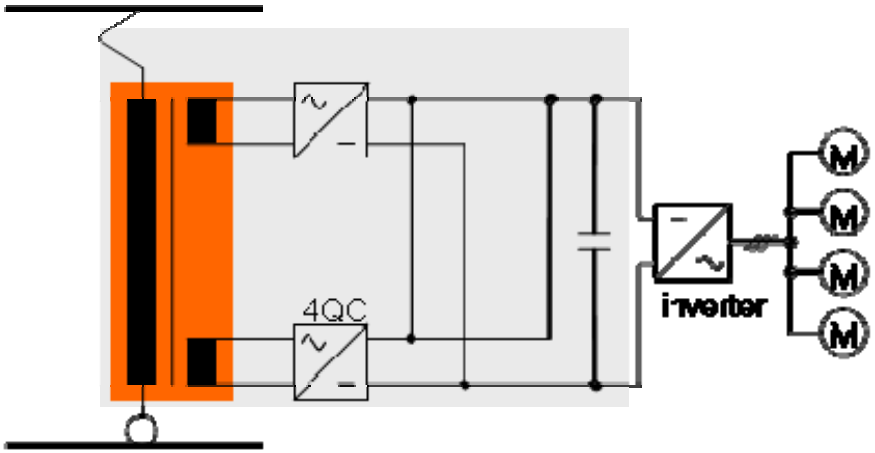
Medium-Frequency Traction Transformer

Jan Weigel

Siemens AG

Basic Concept

conventional

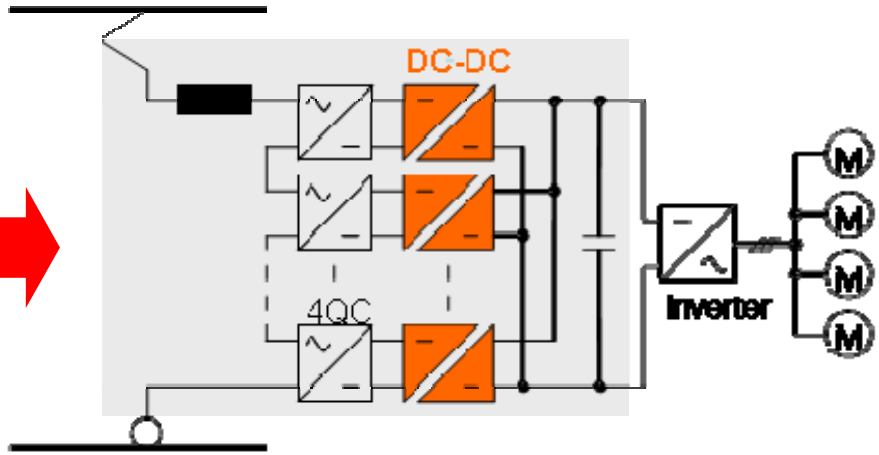


transformer efficiency suffers from its

- mass requirements
- Installation space requirements

however mass and size is large

medium frequency technology



conventional transformer substituted by HV converter comprising

- Line choke
-
-

Advantages

- **efficiency↑**
- **mass/size↓**
- **Scalable platform**
- **Flexible installation**

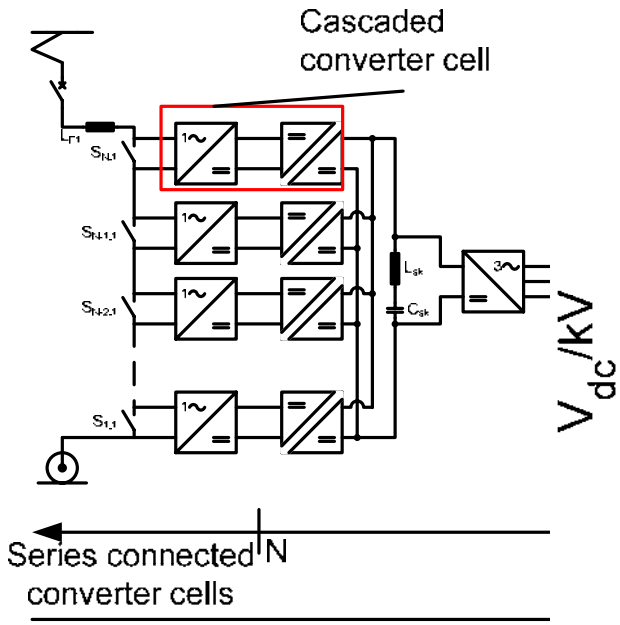
Scope & Objectives

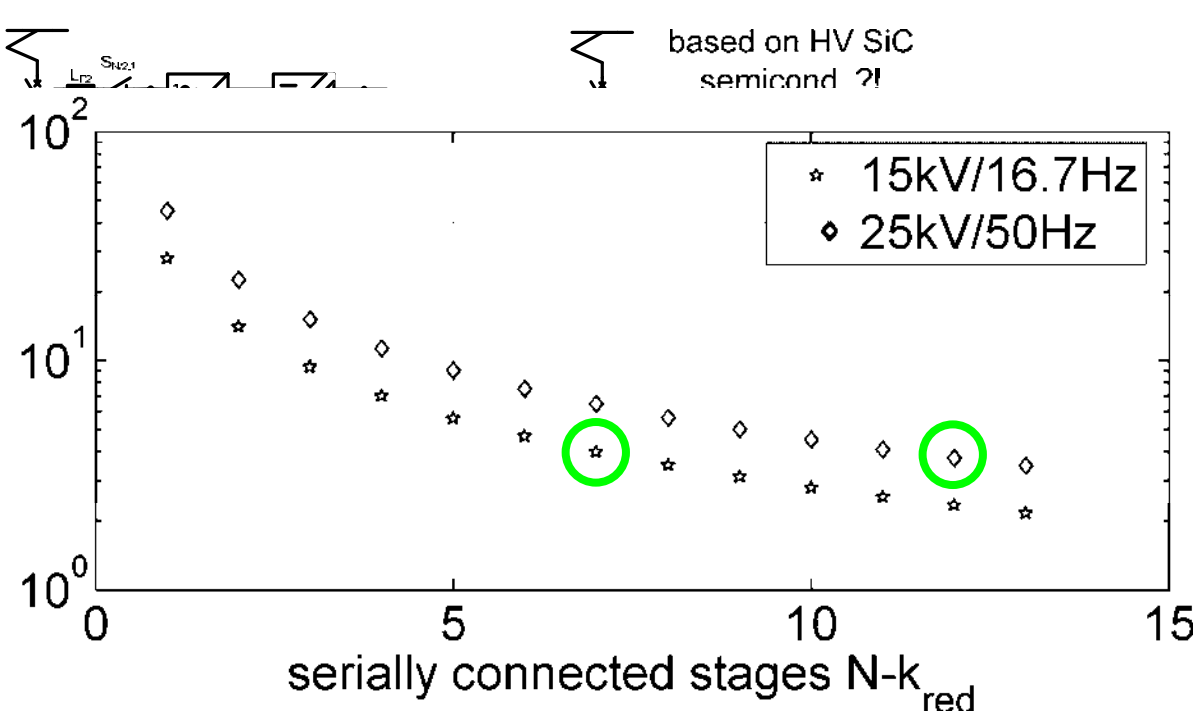
- **Target**: Evaluation of medium-frequency topologies based on available and emerging power semiconductors, Laboratory test-setup
  - Identification of…
    - design options (insulation, cooling, material choice, where to mount the harmonic absorber,…)
    - operational options (medium frequency, catenary side converters)
    - hardware requirements (components…(redundancy, passive line impedance), startup/regular op., fault handling)
    - available, suitable and emerging power semiconductors
  - Evaluation MF- switching of power semiconductor
    - Labprototype testing of key component “MF DC/DC-Converter”

Components – Structure

- HV Module – Choice of individual DC-link Voltage
  - Series connection of N_s HV submodules
  - Series and parallel connection of HV submodules
  - Parallel connection of N_p HV submodules

V_{dc}↑ per submodule

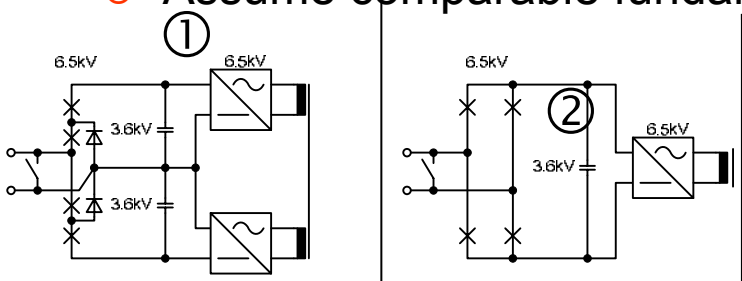




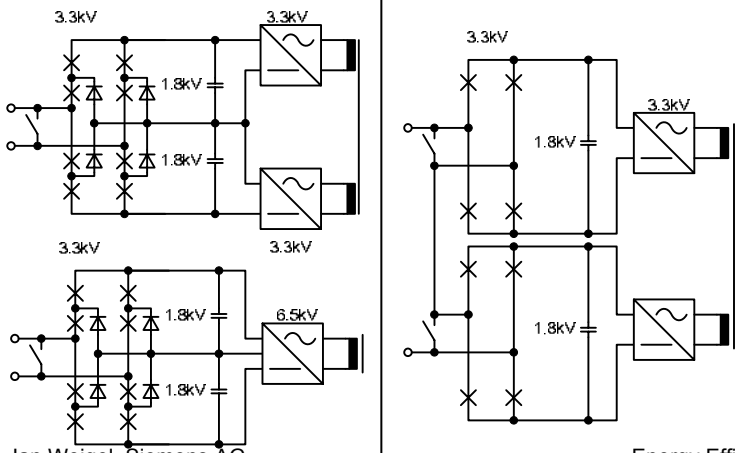
Components – 4QC Cascade

- HV Module – Multilevel or 2 level
  - 1.7kV, 3.3kV and 6.5kV available (there is currently no market for the development of HV SiC devices)
  - Assume comparable fundamental voltage…

A



B



	rating		1	2
# semicond./ 4QC or HV submodule		A	4I/D+2D	4I
		B	8I/D+4D	8I/D
Redundancy/availability	20%	A	O	O
		B	O	+
LF AC performance @ given f_S and chip loading per IGBT	20%	A	O	O
		B	+	+
Complexity (gate drivers, insulation effort, transformer windings, - taps, bushings,…) →reliability	60%	A	O	+
		B	– –	– –

→ 2 level submodules advantageous!

Components – 4QC Cascade, Line choke

4QC cascade

- **# 15kV/25kV →min. 7/12 stages**
- **→3.6kV rated dc voltage**
- **f_S → low as conventional, however significant resulting switching frequency**

Line choke

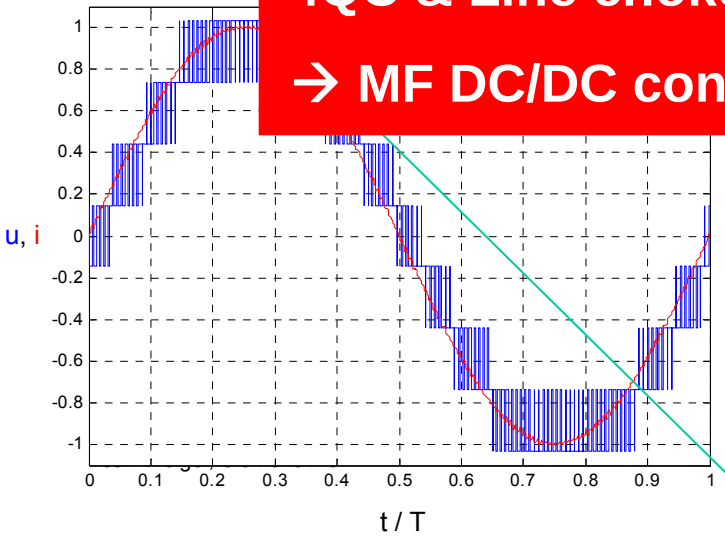
- **Line compatibility**
- **surges**

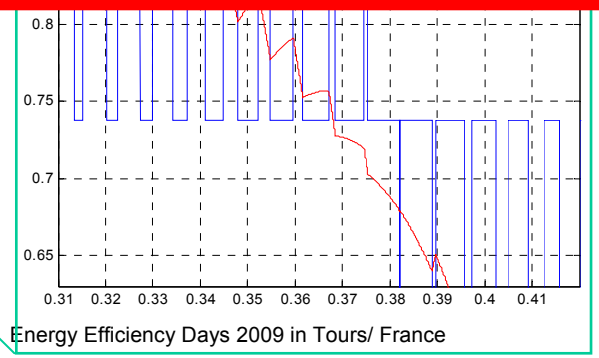
→ passive impedance

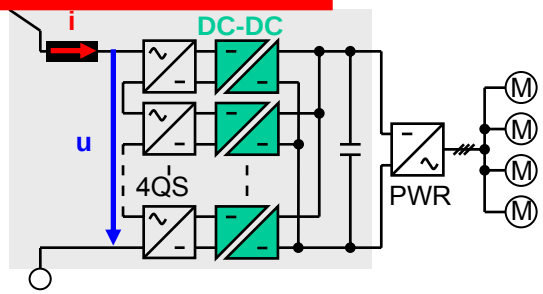
- **Insulation as for conv. transformer**

4QC & Line choke are conventional technology

→ MF DC/DC converter is the innovative component!



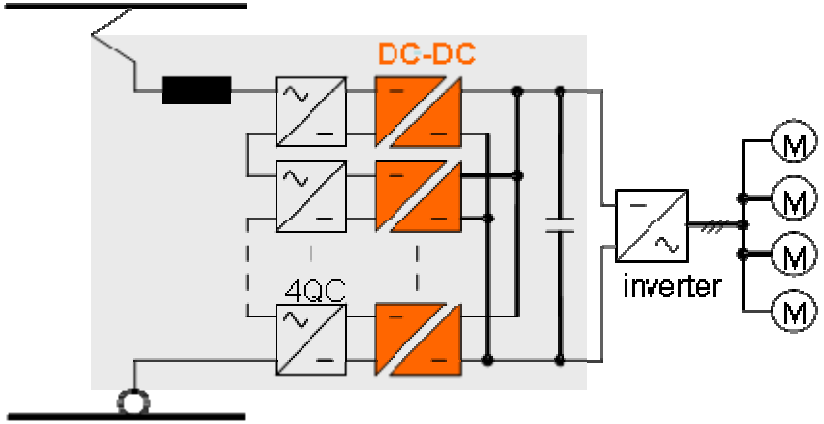




Medium-Frequency Traction Transformer

Components – MF DC/DC Converter

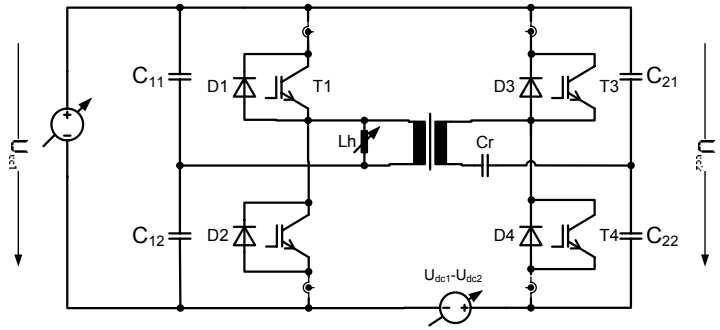
- dual active bridge → Bidirectional power flow (drive&recuperation)
- Pulsating power throughput (harmonic absorber on motor side)
- high power density / small design
  - f_S↑ → transformer mass/size↓
  - High performance cooling
  - low effort for control
- series resonant dc/dc-converter (beneficial)
  →low effort for control of power flow and voltage

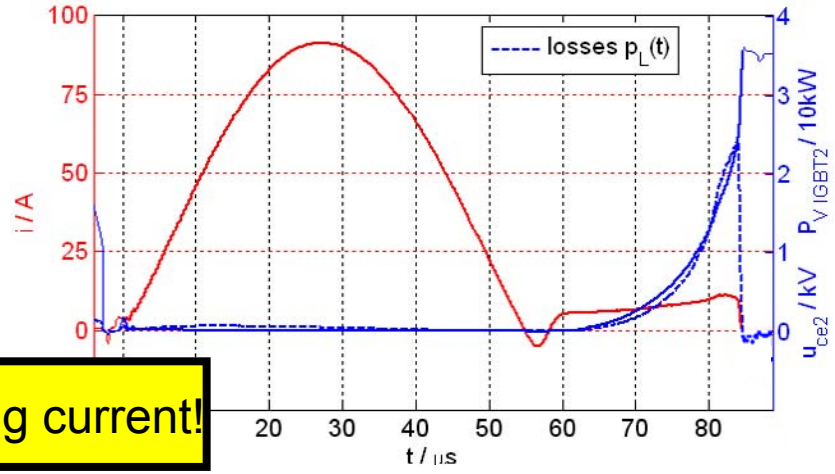


- suitable switching frequency f_S for HV IGBTs in soft switched mode?
- potential of next generations power semiconductors ?

Lab Prototype Testing

- Prototype setup in back-to-back mode
  - Adjustment of…
    - Pulse pattern
    - Magnetizing inductance
    - Difference voltage
  - Target
    - Suitable switching frequency @ optimized operation
    - Suitable utilization and efficiency





Best measure for f_S ↑→ appropriate magnetizing current!

- suitable switching frequency f_S for HV IGBTs in soft switched mode?
- potential of next generations power semiconductors ?

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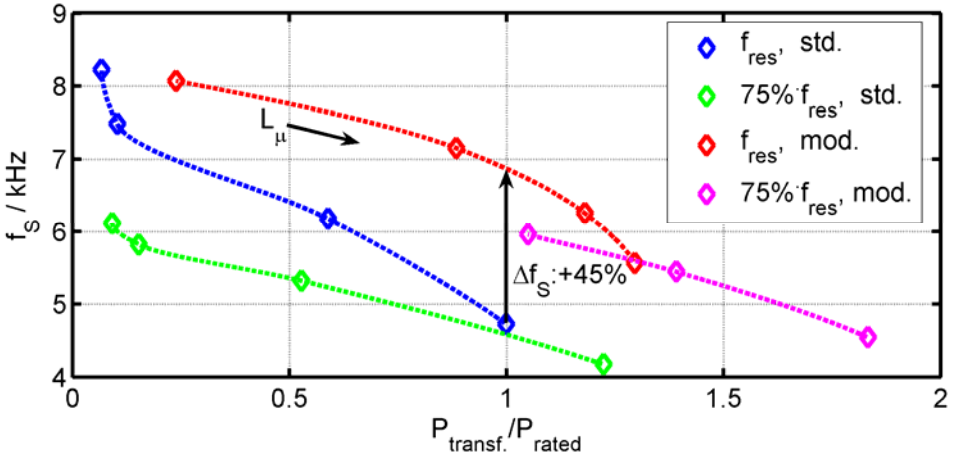
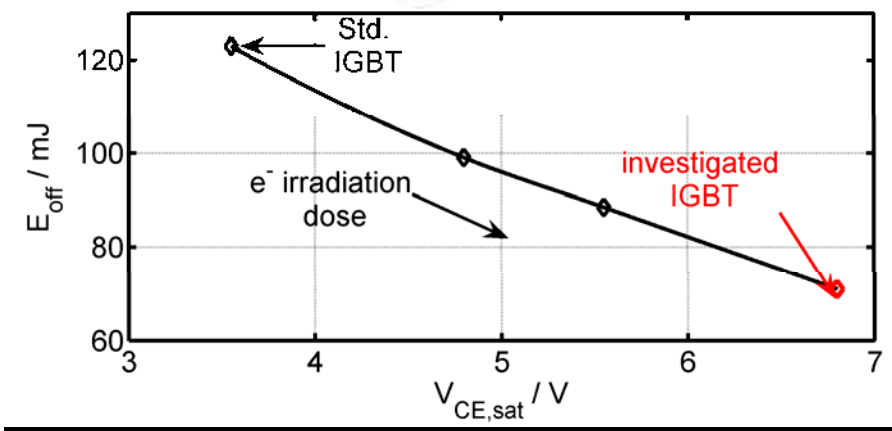
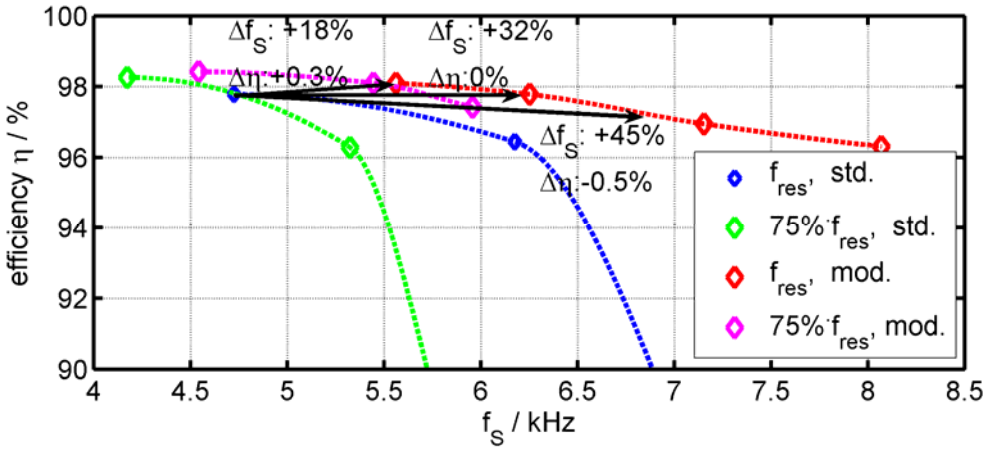
Standard ↔ Modified IGBTs

- e^- irradiation →shift trade-off between switching and conduction loss
- Comparison between latest std. and modified IGBTs







- suitable switching frequency f_S for HV IGBTs in soft switched mode?
- potential of next generations power semiconductors ?

Promising Applications

EE Potential of MF- technology by application

[Source: *]

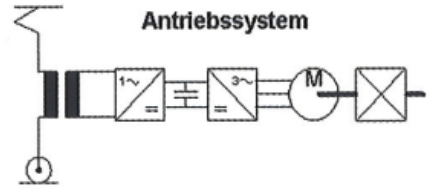
- city train (BR425) → ☺
  - low rated efficiency
  - strong overload (160% due to reasons of installation space and mass) → average efficiency↓

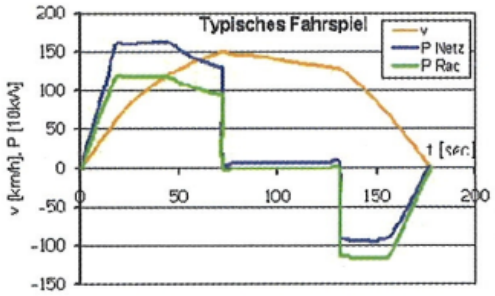
[Source: *]

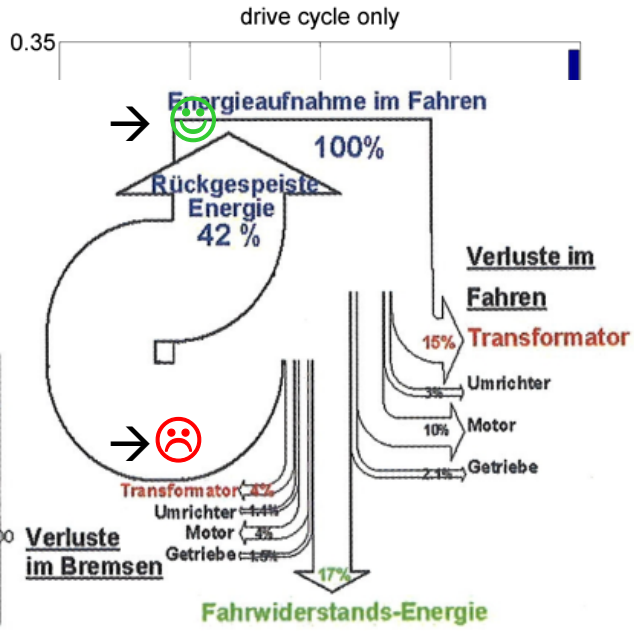
- High speed trains
  - efficiency restricted
  - mostly close to max

[Source: *]

- Locos (e.g. Tauru
  - comp. high rated eff
  - much partial load →





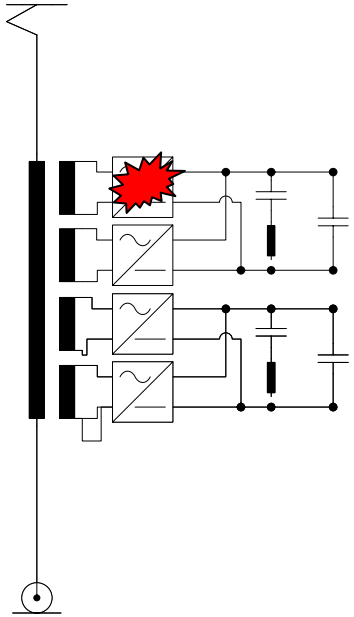


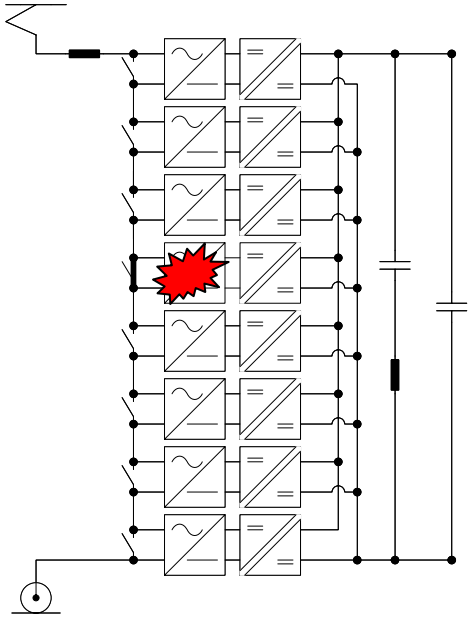
* Moderne Drehstromantriebstechnik – Stand und Perspektiven, ZEVrail Glasers Annalen

[Source: *]

Availability: conventional/MF technology

- **Redundancy implemented due required voltage margin @ any power electronic defect**
- **Comp. : Conventional** **MF transformer**





50% $P_{traction}$ **87.5%/92% $P_{traction}$ (15/25kV)**

Next Steps & Outlook

- Passive line impedance → final commitment
- Report: D5.3.4 Validation data documentation of the medium – frequency power stage
- Contribution to Global Model: Efficiency characteristics

  → Evaluation of Energy Efficiency within Global Model