Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

Isolated DC-DC Converter for Battery Storage in Traction Applications - Medium Frequency Building Block for Future of Railway -

One-third of the worldwide primary energy is consumed in the transport sector, which causes a large amount of greenhouse gas emission and pollution. In order to reduce the environmental impact of transportation, alternative propulsion systems, as for example hybrid electric vehicles, are investigated. In addition to cars, hybrid propulsion concepts are recently also investigated for locomotives, which are extended by an on-board battery system.

By recuperating breaking energy and by reusing it during the acceleration of the train, the power fluctuations in the railway grid can be significantly reduced, and also enables an additional degree of freedom for designing highly efficient locomotive propulsion systems. Moreover, with the energy stored in the batteries, the locomotive can drive on not electrified tracks (e.g. shunt yards) without a diesel engine avoiding air pollution and emission of greenhouse gases.

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Locomotive use case

- Isolation voltage and ambient temperatures detrimental for achieving the weight and dimension constraints.
- High efficiency and integration crucial for reaching these goals.

| Battery Voltage Range | 518...835V |
| Nominal DC Link Voltage | 1200V |
| Regulated DC Link Voltage (peak) | 1500V |
| Unregulated DC Link Voltage (peak) | 1200V |
| System Power | 183kW |
| System Power (peak) for pros | >234kW |
| Current per Battery (continuous) | 210A |
| Current per Battery (peak) for pros | 280A |

| Working Insulation Voltage | 4.3kV |
| Impulse Withstand Voltage P-S | 8kV |
| Efficiency | > 95% |
| Ambient Temperature | 75°C |
| Cooling Medium Temperature | 60°C |
| Maximum Dimensions | 705x612x20 cm |
| Maximum Weight | 25 kg |

Selected measurement results

Current control mode - Full power reversal 700V / 60A
Transformer voltage and current waveforms

Expected impact

The battery system enables to store recuperated energy during braking, what reduces the total energy consumption and enables reuse of the recuperated energy during the acceleration phase. Additionally, energy stored in the batteries can be used to drive the locomotive on non-electrified tracks without a diesel engine, avoiding CO₂ emissions (e.g. in shunt yards).

References


Partners

HPE
Laboratory for High Power Electronic Systems

ETH Zürich

Bombardier Transportation
(Switzerland) AG
Brown-Boveri-Str. 5, Zürich, Switzerland

Standardization and modularization

- Scalable solution: 1 or more energy storage systems per MITRAC propulsion system
- Standardized hardware independent interfaces to MITRAC propulsion system
- Applicable for all vehicle families from LRV’s to locomotives
- ‘Plug and play’ solution – modular and scalable

Medium frequency DC-DC building block

- Modular Dual Active Bridge (DAB) topology
- SiC MOSFETs as main switches
- Foil winding, ferrite core transformer

Characteristics

- Diesel
  - 1500V-1800V
  - 1200kWh
  - 600kW
- Fuel Cell
  - 500V-600V
  - 534kWh
  - 200-400kW
- Battery
  - 500V-900V
  - 24.5kWh
  - 600kW
- Supercaps
  - 500V-900V
  - 2kWh
  - 600kW

Requirements

- LRV
  - 4 modules Parallel Input / Parallel Output
- Main Line (Commuter, Regional, …)
  - 3 modules Parallel Input / Series Output
- Locomotives
  - 4 modules Parallel Input / Series Output

Transformer Voltage and Current Waveforms

Measurement setup

4 modules
Parallel Input / Parallel Output
3 modules
Parallel Input / Series Output
4 modules
Parallel Input / Series Output

200kW
750V Line
200kW
750V Line
200kW
1500V-2000V
200kW
1500V-2000V

Battery Voltage Range
518..835V

Nominal DC Link Voltage
1200V

Regulated DC Link Voltage (peak)
1500V

Unregulated DC Link Voltage (peak)
1200V

System Power
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System Power (peak) for pros
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Working Insulation Voltage
4.3kV

Impulse Withstand Voltage P-S
8kV

Efficiency
> 95%

Ambient Temperature
75°C

Cooling Medium Temperature
60°C

Maximum Dimensions
705x612x20 cm

Maximum Weight
25 kg

4.2kV

18kV

> 95%

75°C

60°C

705x612x20 cm

25 kg

Isolation voltage and ambient temperatures detrimental for achieving the weight and dimension constraints.

High efficiency and integration crucial for reaching these goals.