Paris Session 2022

Opportunities for Solid State Transformers

A2 - PS2: Q6

What prospects are there for development and use of electronic or solid-state transformers?

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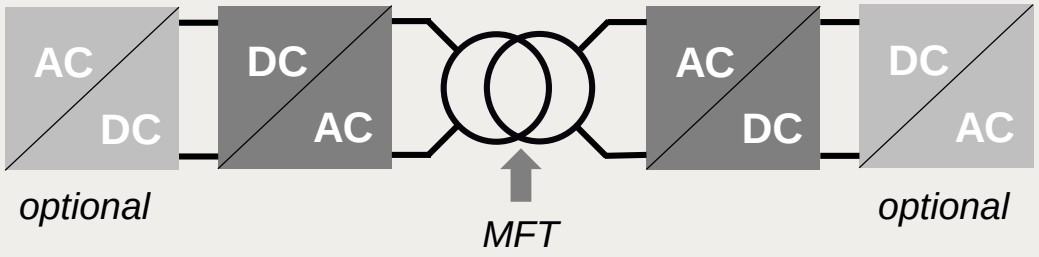
HITACHI
Inspire the Next

SST Introduction

What is an SST?

A modular converter based on MFTs, able to provide:

- xC-xC conversion with galvanic insulation
- Fully controllable power (phase and voltage in AC)
- It can provide a MV/LV conversion

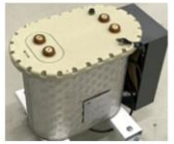


SST cell – several cells can be connected in series to reach MV

What are the benefits of SSTs?

- Key enabler of DC/DC power conversion at MV level
- Enable DC link between DC sources, loads and storage
- Reduced transformer size due to high frequency (~kHz)

$$A_{Core}A_{Wdg} = \frac{\sqrt{2}}{\pi}\frac{P_t}{k_W J_{rms}\hat{B}_{max} f}$$



3'000kg, FL efficiency 99,0%

LFT – 50 Hz

150kg, FL efficiency 99,6%

MFT – 20'000 Hz

AC-AC Conversion

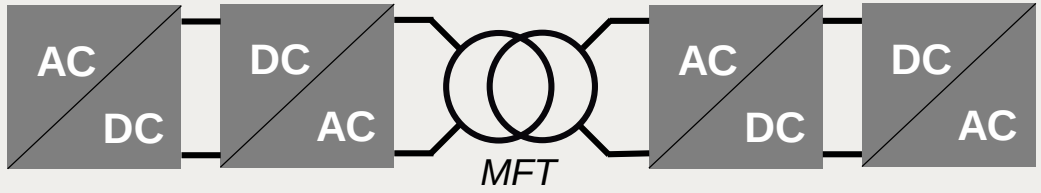
SST vs. Standard Solution

- Compatible with existing MV AC infrastructure
- Provides full controllability: power, phase and voltage
- With 5 conversion stages, it is difficult to beat a single stage low-frequency transformer in terms of cost & efficiency
- Possible weight decrease is not the most important KPI in utility applications
- An interesting compromise is the «Hybrid transformer» for the AC/AC applications [1]

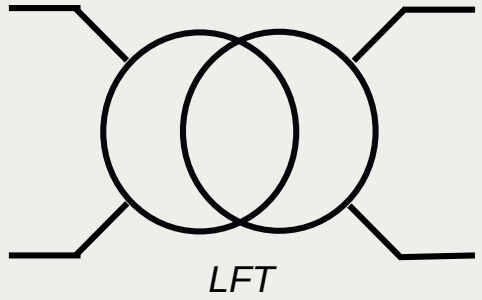
Conclusion

- AC-AC MV applications are unlikely to drive the SST development

Principal schematic of AC-AC SST



MV line frequency distribution transformer (LFT)



[1] J W. Kolar, J. E. Huber, "*Next-Generation Datacenter MV Interfaces - Will Solid-State Transformers Meet Their Waterloo?*", Ind. session presentation, APEC 2022

AC-AC Conversion

SST vs. Standard Solution

- 3-phase AC grids
- Many voltage levels: 3.3, 4.16, 6, 11, 15, 20kV…
- Grid frequency: 50Hz or 60Hz
- Sub-station installations
  - Weight / footprint reduction - not that relevant
- Reliability - very complex due to 3-phases
- Efficiency - hard to beat distribution LFT
- Control - improved compared to existing solutions
- Higher cost

MV AC SST Substation

GE’s 13.8kV to 465/√3V,60Hz, 1MVA SiC SST
(Source: www.ge.com)

AC-DC Conversion

SST vs. Standard Solution

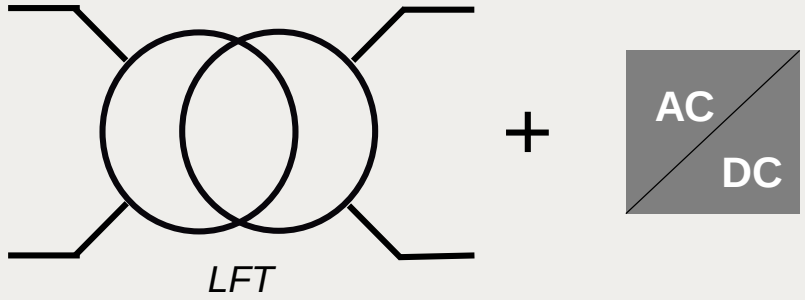
- Compatible with existing MV AC infrastructure
- AC-DC is more favorable as compared to AC-AC
- SST has 1 less while LFT has 1 more conversion stage as compared to AC-AC
- AC-DC SSTs can be interesting in applications where the efficiency vs. weight ratio is challenging (railway [2]) or when multiple LVDC outputs are needed (e-mobility [1])

Conclusion

- Due to backward compatibility with MV AC distribution applications such as railway and e-mobility may be the first adopers of the SST technology.

Principal schematic of AC-AC SST

MV LFT plus LV rectifier



[2] D. Dujic, F. Kieferndorf, F. Canales, and U. Drofenik, “Power electronic traction transformer technology,” Power Electronics and Motion Control Conference, Jun. 2012

AC-DC Conversion

Railway

- 1-ph AC grids - 15kV (16.7Hz) or 25kV (50Hz
- On-board installations - serious space constraints
- Volume and Weight reduction - system savings
- Efficiency - easy to beat traction LFT
- Control - similar to existing solutions
- Reliability, cost - high number of devices?

➢ 3xPn boost in same volume

➢ 1y succesfull operation in the field

[2] ABB's 1ph, 1.2MW, 25kV 16,7Hz PETT
(Source: www.abb.com)

EV Charging

- 3-ph AC (50, 60Hz) - 3.3, 4.16, 6, 11, 15, 20kV…
- Footprint and weight - a factor for installation costs
- Reliability - more complex due to 3-phases
- Efficiency - improved compared to state of the art
- Control - similar
- Cost savings on installation

➢ 90% size savings 0.5MW/m3

➢ Instalation in 1 day

➢ 25% redundancy

Resilient Power's up to 3.2MW, 15kV 50/60Hz SST
(Source: www.resilientpower.com)

DC-DC Conversion

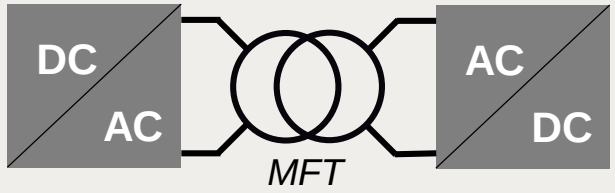
SST vs. Standard Solution

- SST is the natural solution for DC-DC conversion
- State of the art 50Hz devices can also be used for the sake of availability, but SST will ensure better efficiency and lower cost in the DC-DC application
- Efficiency such as 98,9% @ full load can be reached by the SST for the full DC-DC

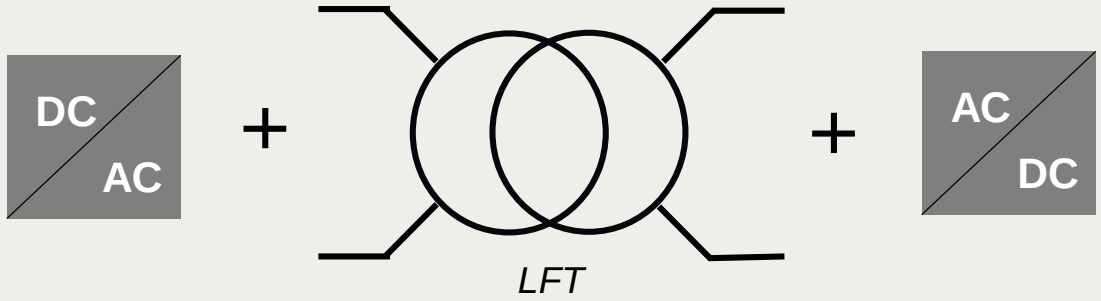
Conclusion

- MVDC distribution will be the main driver of SST in the medium to long term

Principal schematic of DC-DC SST



MV LFT plus MV DC-AC inverter and LV rectifier

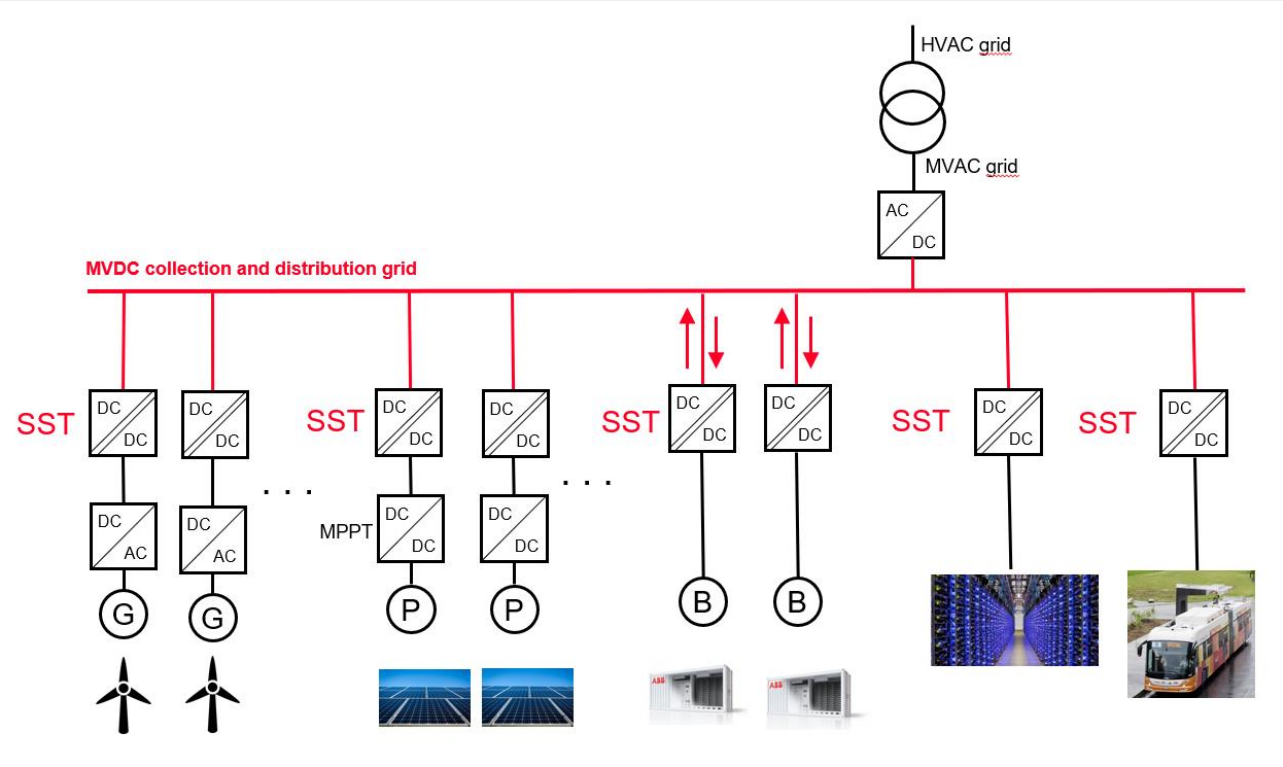


MVDC Grids

Key advantages of MVDC grids

- More efficient power distribution
  - More power per cable cross-section
  - Reduced cabling cost
  - Reduced cabling losses
- Reduced conversion losses from DC source to DC load
- Less power quality management issues
- No frequency synchronization needed
- Controllability enabled by SST
- Link between AC grids with different properties
- Detailed analysis of MVDC application available in [3]

MVDC Grid Vision



[3] "*Medium Voltage DC Distribution Systems*" CIGRE Technical Brochure C6/B4, July 2022, Reference: 875

MVDC Grids – Possible First Adopters

Marine LVDC / MVDC Distribution

- System level benefits
  - No frequency synchronization of generators
  - Integration of storage technologies
- No need to comply with TSO or DSO
  - Islanded micro-grid
  - Internal parameters can be freely set
  - Protection coordination

Conclusion

- MVDC distribution and therefore the SST as enabling technology can bring significant benefits to ship microgrids without the additional burden of strict TSO and DSO policies.

Example of a MVDC ship distribution

(Source: www.abb.com)