

Project Title:

EV chargers, developing an active bidirectional charger able to provide ancillary services

Expected results:

Prototype of bidirectional charger for providing ancillary services; strategies for optimized electric grid management.

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❑ EV development

Pollution reduction in cities

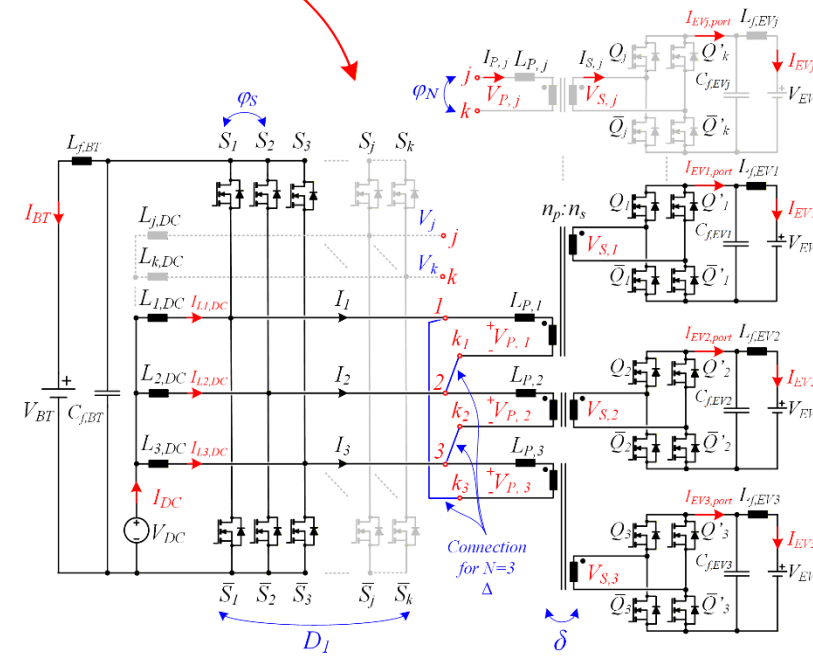
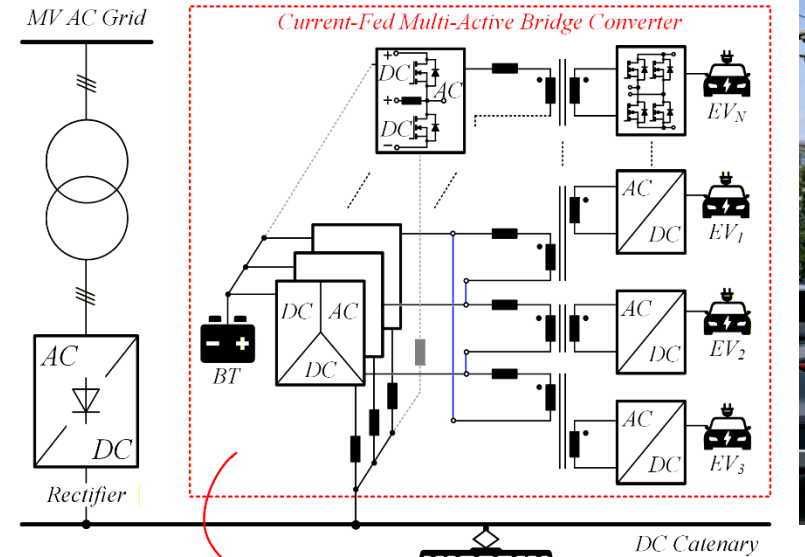
- *~30 million NOW ↗ 80 mln EVs by 2030*

~280 billion € investment
in EV charging infrastructure up to 2030 (in EU and UK)

[1] IEA, "Global EV Outlook 2025". [Online]. Available:
<https://www.iea.org/reports/global-ev-outlook-2025>



- ❑ **No rectification stage** is needed at the charging station (traction station rectifier is used)
- ❑ Usage of existing infrastructure (**Increased** traction substation **utilization**)
- ❑ **Increased** traction transport efficiency (braking energy recuperation)
- ❑ Traction DC grid **voltage stabilization**



Relevance (AC vs DC Tracton Grids)



**Light Rail
Urban Transport**

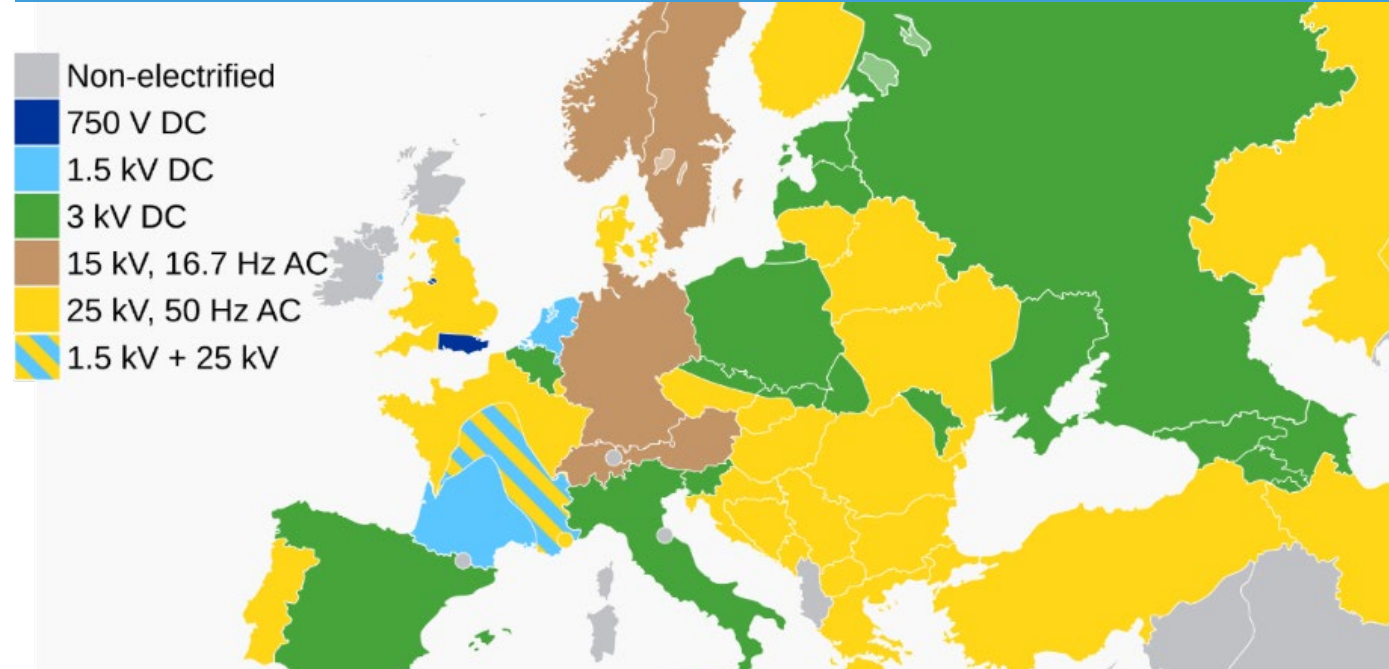
< 1.5 kV



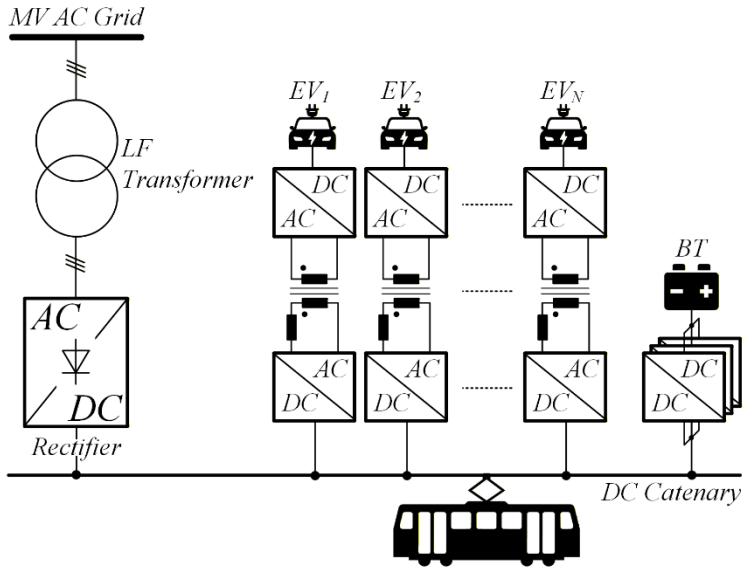
**High Speed
Power Trains**

> 1.5 kV

Integration of EV chargers with Light Rail DC grids is more feasible (more coverage in urban areas)

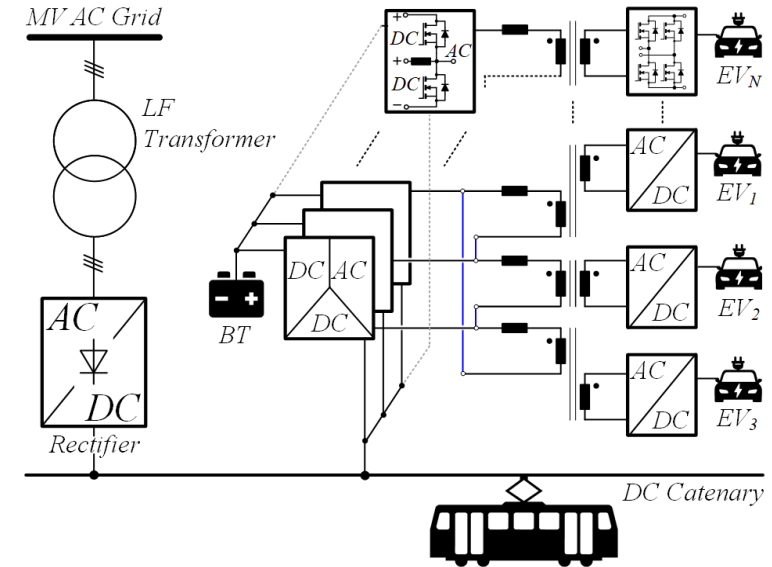


Independent converters



- Independent** converters operation.
- Scalability & Reliability** are HIGH.
- High** number of components ($8N+6$, where N-number of EV chargers).
- Longer** energy conversion paths between units.
- EVs are charged from **unstable** DC traction grid voltage.

Multiport converter

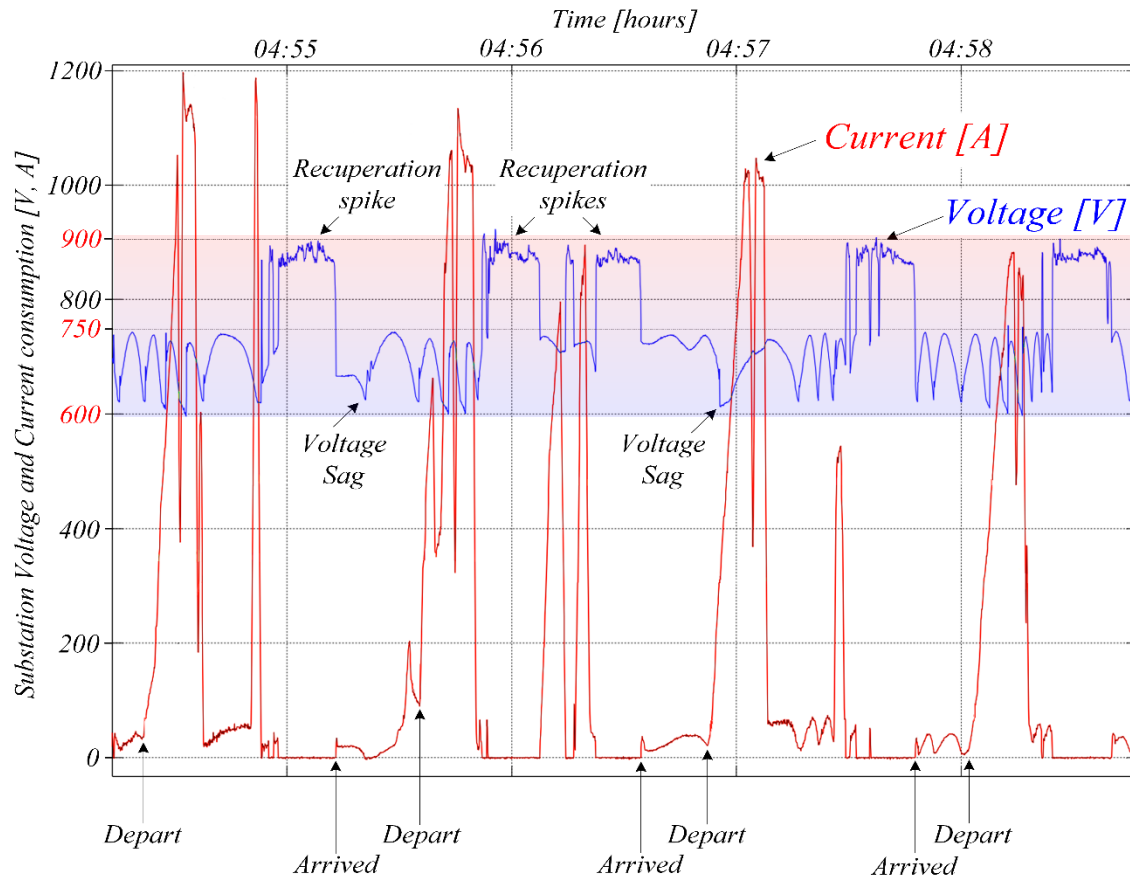


- Reduced** numbers of components needed (only $6N$).
- Potentially **lower** installation cost.
- Independent** converters operation.
- Lower** conversion path between ports.

Challenges

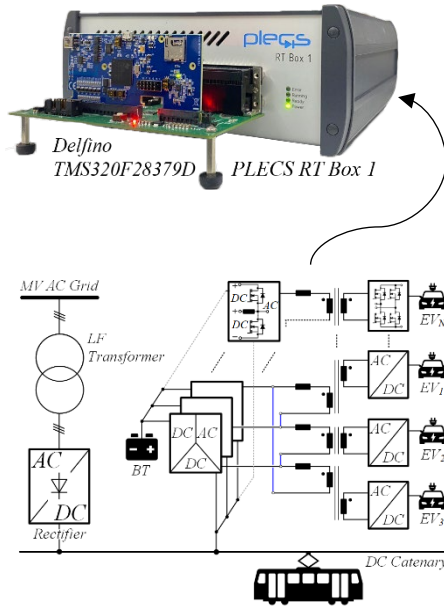
- Finding the **optimal connection point**.
- Substation **overloads** (smart charging has to be used).
- Wide** input voltage range of the converter.

Power consumption from a substation in Göteborg, Sweden (Nominal 1250kVA, 750V)

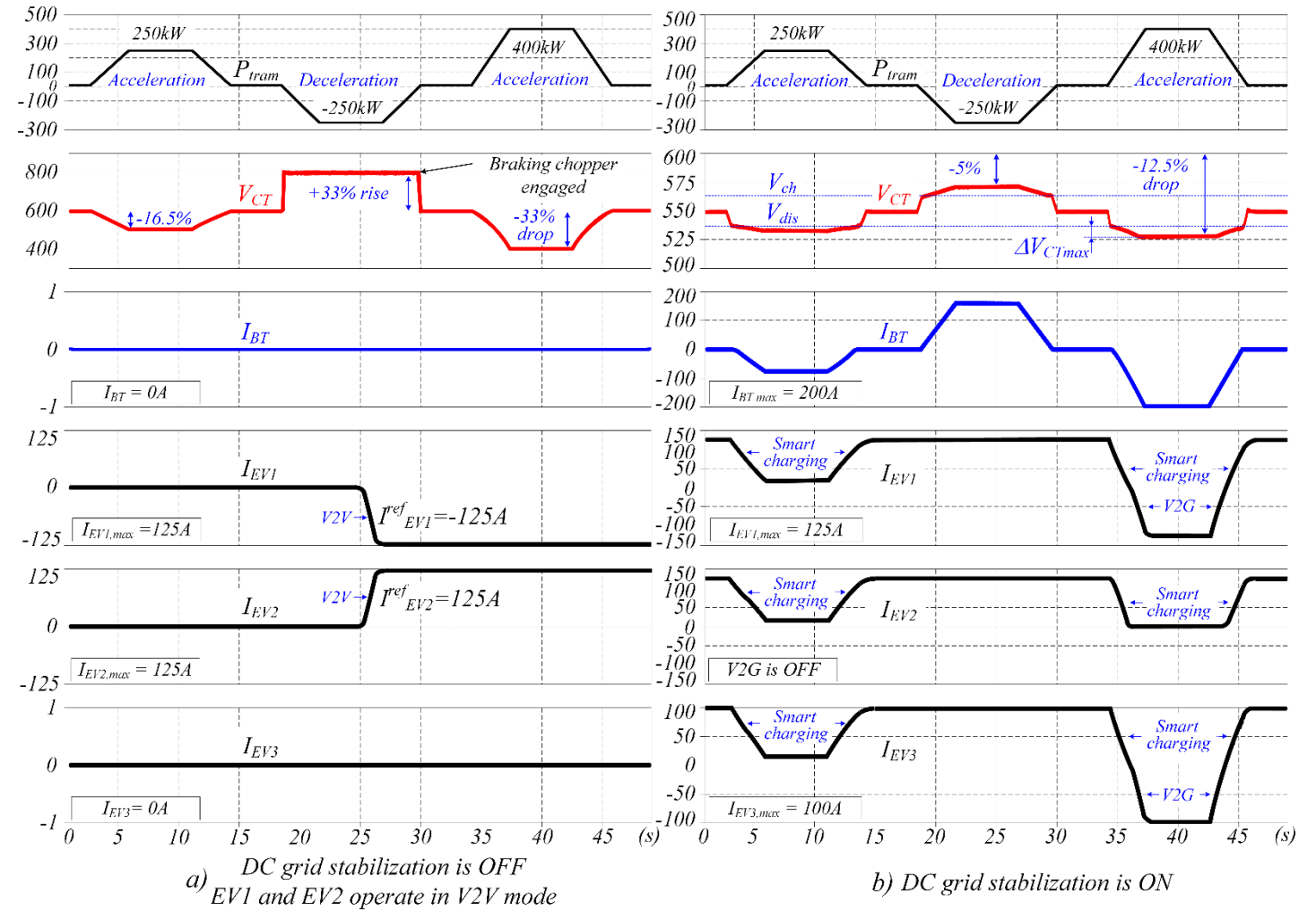


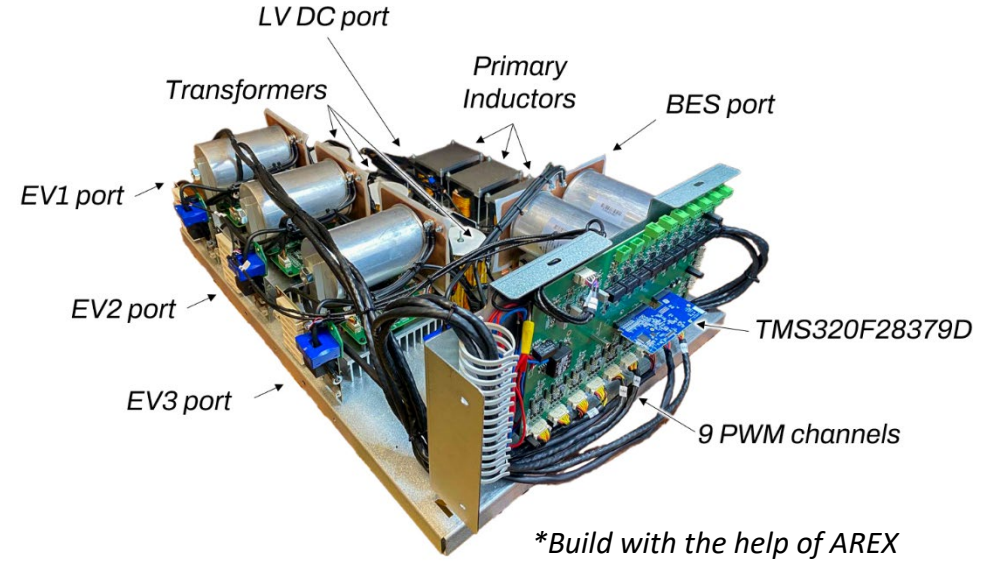
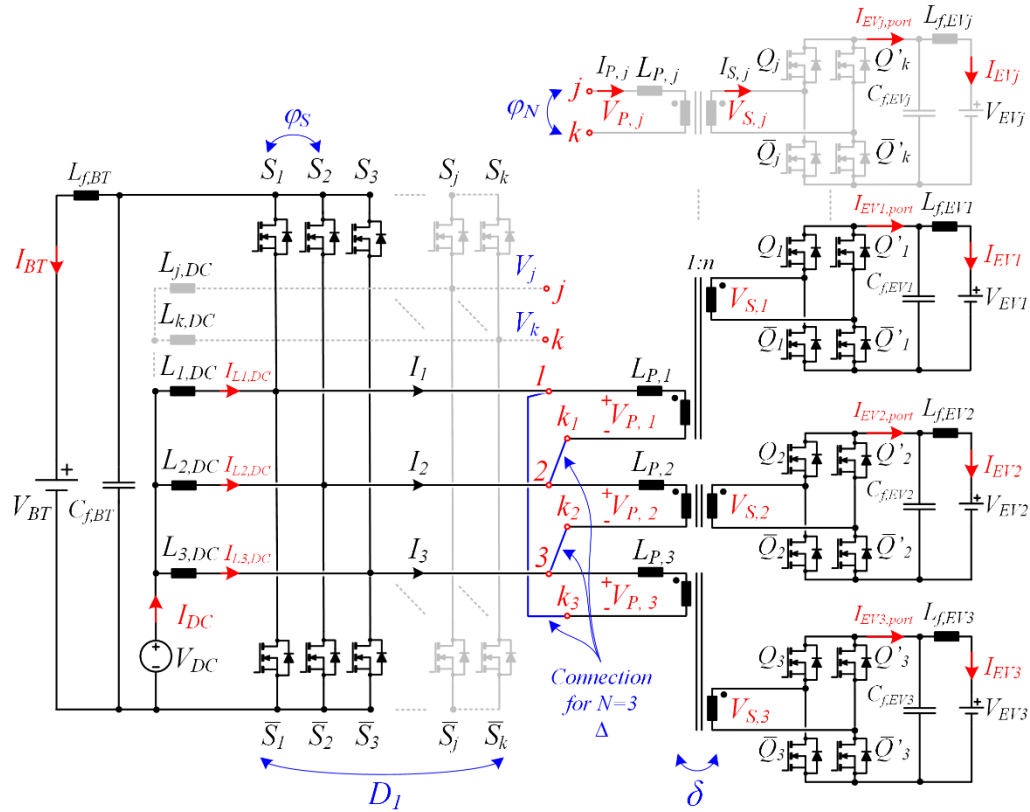
- Voltage **fluctuates** in range **~0.8...1.2** of nominal.
- 10-20%** of consumed energy can be **recuperated** and voltage spikes at the point of connection can be eliminated.
- Voltage **drops** can be **eliminated** by discharging buffer battery & EVs, providing V2G operation.
- EVs and BT smart charging must be applied.**

System operation with 3 EV chargers and battery storage



- Real-time simulation have shown system ability to completely **eliminate** voltage surges and **reduce** DC grid catenary **voltage drops** to **-12.5%** by means of BT and EVs aggregated charging and discharging.





**Build with the help of AREX*

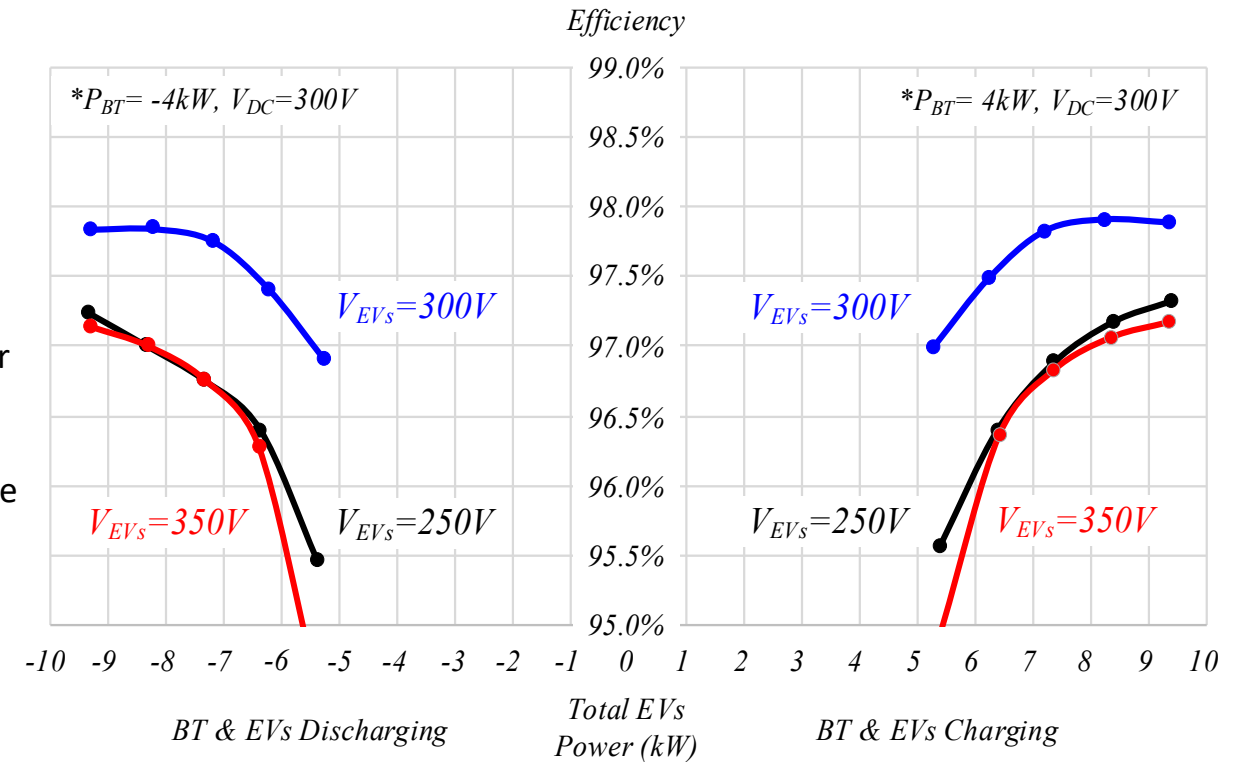
- Off-board
- Fast
- Multiterminal
- Public

charging station located **near urban railway transit hubs**

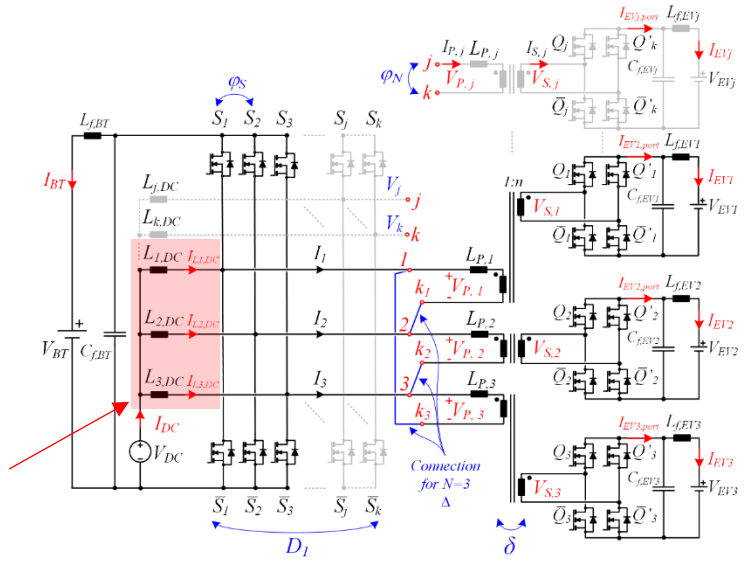
- with dedicated Battery Storage

3 port CF-MAB converter efficiency

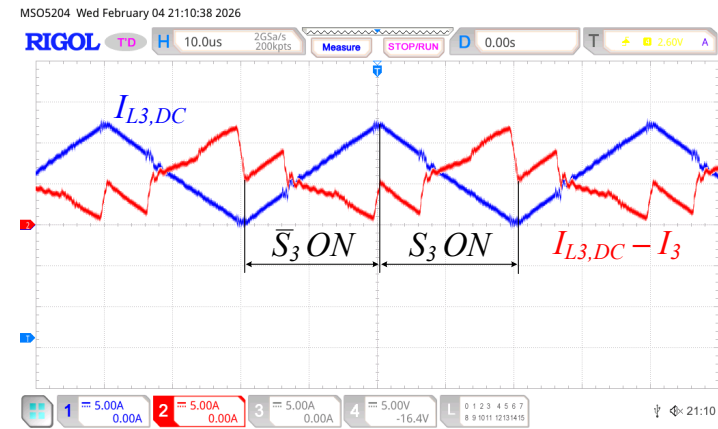
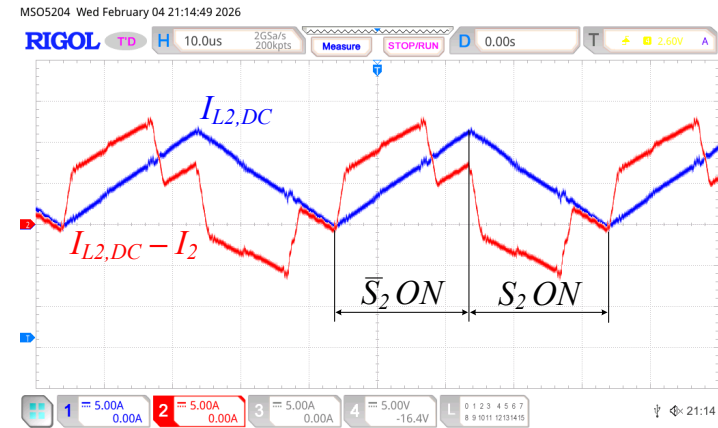
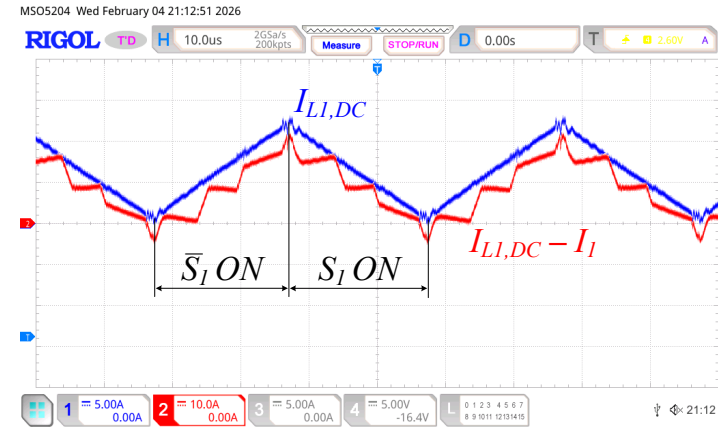
- ❑ The converter has shown **high efficiency of ~97.8%** peak at 9.5kW, when EVs voltage $V_{EVs}=300V$ is matched with a BT voltage $V_{BT}=600V$ using a transformer with $n=0.5$.
- ❑ During the mismatch, when $V_{EVs}=250V$ or $V_{EVs}=350V$, **efficiency is reduced** due to increased transformer and switches RMS currents.



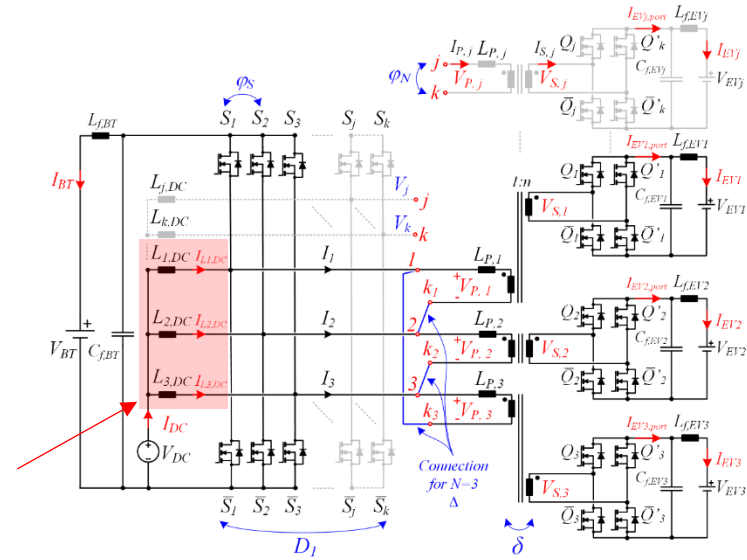
Phases balancing problem



- ❑ Different ports load causes **imbalance** in primary side inductors currents
- ❑ Current of each inductor has to be measured and actively **balanced**



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EV, BT and DC grid voltages are the same:

- ❑ $V_{EV1}=350\text{ V}, V_{EV2}=300\text{ V}, V_{EV3}=250\text{ V}$
- ❑ $V_{DC}=200\text{ V}, V_{BT}=600\text{ V}$

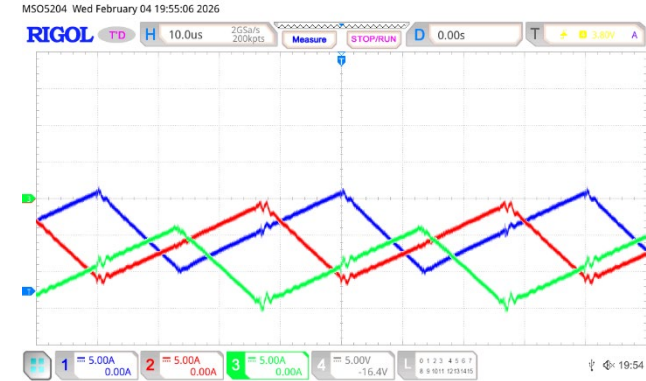
Charging power in test 1:

- ❑ $P_{EV1}=-1\text{ kW}$
- ❑ $P_{EV2}=-2\text{ kW}$
- ❑ $P_{EV3}=3\text{ kW}$

Charging power in test 2:

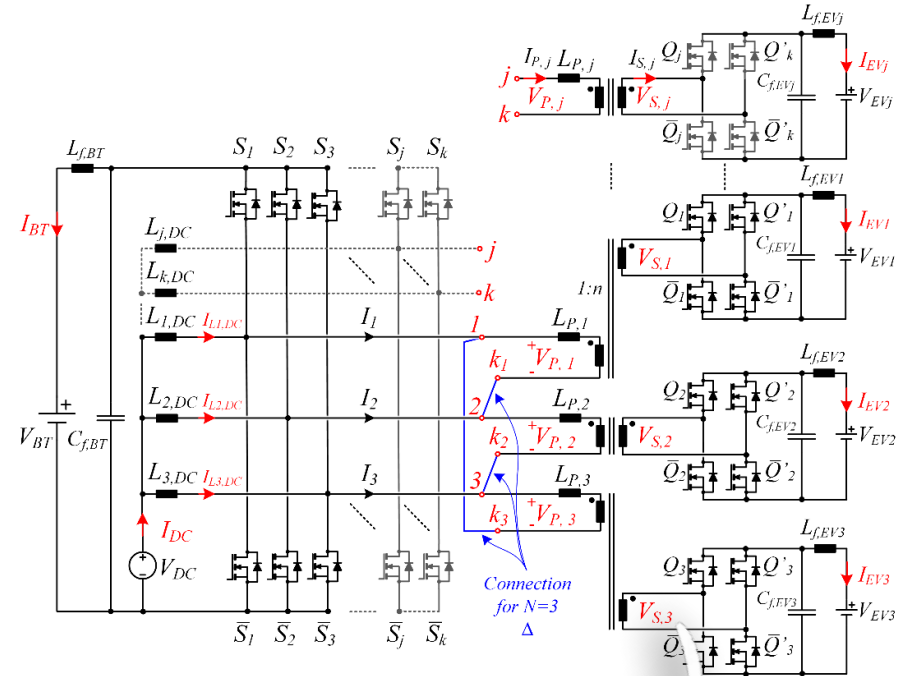
- ❑ $P_{EV1}=-2\text{ kW}$
- ❑ $P_{EV2}=3\text{ kW}$
- ❑ $P_{EV3}=0\text{ kW}$

❑ Primary inductors current



Overall system features

- ❑ Integrates storage battery and EV chargers into LV DC grid.
- ❑ Completely eliminates voltage surges in the point of connection and reduces DC grid catenary voltage drops.
- ❑ Improves traction transport efficiency by 10–20% by recuperating braking energy.



Current Fed Multi-Active Bridge Converter

- ❑ Reduced number of switches (6N for CF-MAB vs 8N+6 for independent connection).
- ❑ Independent and bidirectional EV and BT ports operation, allowing V2G, V2V services.
- ❑ Ports scaling ability.



Journal Publications (High Impact Factor Q1-Q2):	Journal Publications (Medium-Low Impact Factor):	Conference Publications:	Awards:	Book Chapter:	Patent:
					
3+1*	2+1*	6+1*	3	1	1

*waiting publication

1. M. Lukianov, E. Romero-Cadaval, A. Kaspruwicz, O. Husev and R. Strzelecki, "Scalable Multiport DC-DC Converter for Bidirectional EV charging in DC Traction Grids," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, doi: 10.1109/TCSII.2025.3572290.
2. Verbytskyi, I.; Lukianov, M.; Nassereddine, K.; Pakhaliuk, B.; Husev, O.; Strzelecki, R.M. Power Converter Solutions for Industrial PV Applications—A Review. *Energies* 2022, 15, 3295. <https://doi.org/10.3390/en15093295>
3. G. Arena, A. Chub, M. Lukianov, R. Strzelecki, D. Vinnikov and G. De Carne, "A Comprehensive Review on DC Fast Charging Stations for Electric Vehicles: Standards, Power Conversion Technologies, Architectures, Energy Management, and Cybersecurity," in *IEEE Open Journal of Power Electronics*, vol. 5, pp. 1573-1611, 2024, doi: 10.1109/OJPEL.2024.3466936.
4. M. Lukianov, P. Derkacz and R. Strzelecki, "Multi Active Bridge converter with DPS modulation for bidirectional EV charging from DC traction grid," *IECON 2024 - 50th Annual Conference of the IEEE Industrial Electronics Society*, Chicago, IL, USA, 2024, pp. 1-7, doi: 10.1109/IECON55916.2024.10905342.
5. M. Lukianov, E. R. Cadaval, G. Arena and R. Strzelecki, "Partially Isolated Multi-Active Bridge DC-DC Converter with Bidirectional EV Charging Ports," 2024 IEEE 18th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG), Gdynia, Poland, 2024, pp. 1-7, doi: 10.1109/CPE-POWERENG60842.2024.10604312.

