



The logical next step: **Bipolar LVDC**

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Why bipolar LVDC?

Transfer **more power** while **retaining two voltage levels**

Why LVDC?

Higher **compatibility**

Higher power transfer **capability**

Higher **controllability**



DC devices



Solar photovoltaics



Heating, ventilation & airco

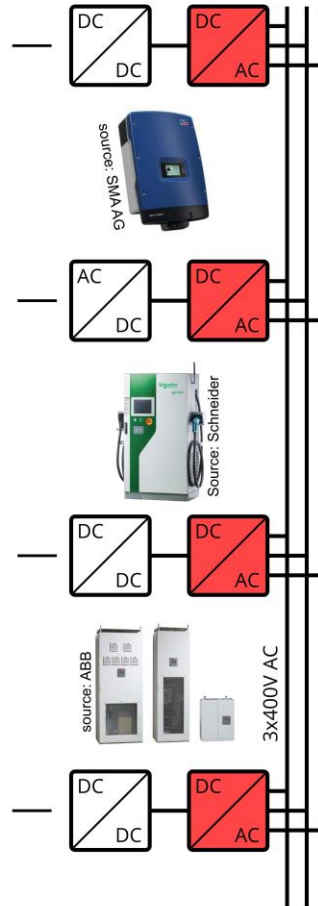


Electric vehicle charging



Battery storage

AC vandaag



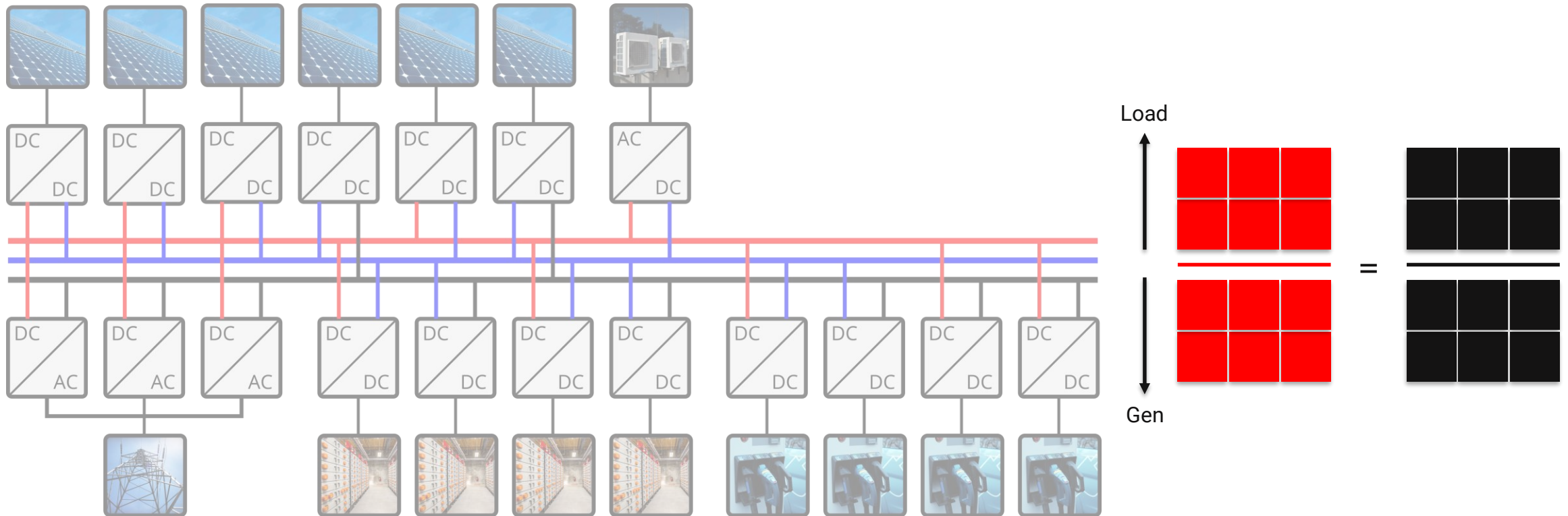
Why bipolar LVDC?

Higher power transfer capability

Two voltage levels available

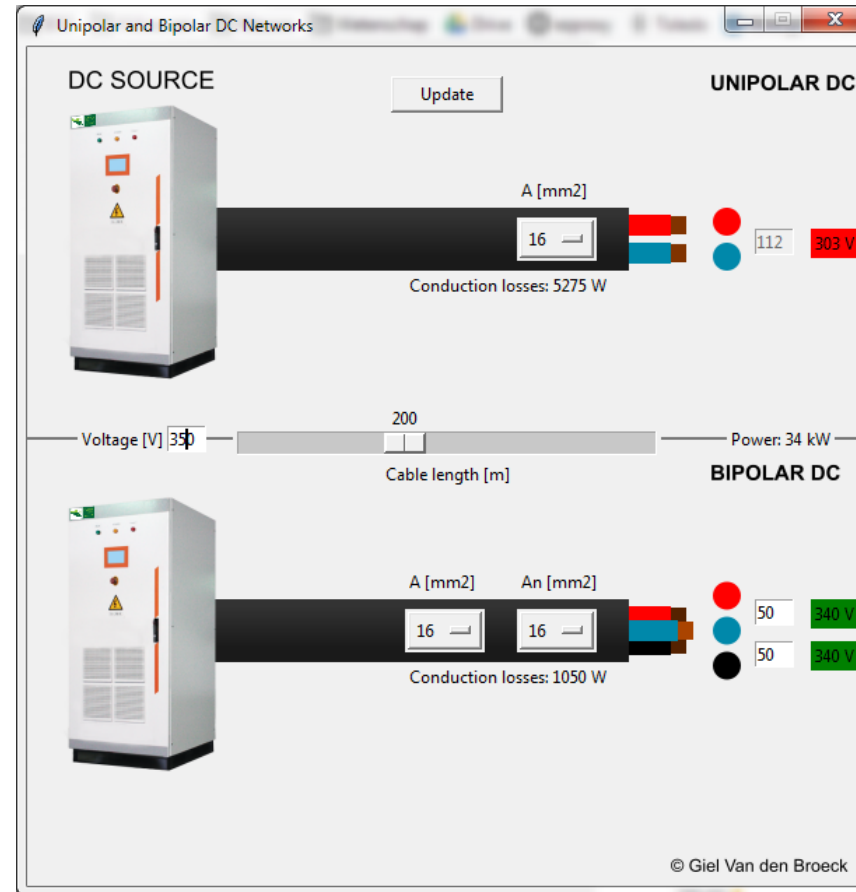


How to keep the pole-to-neutral voltages balanced?

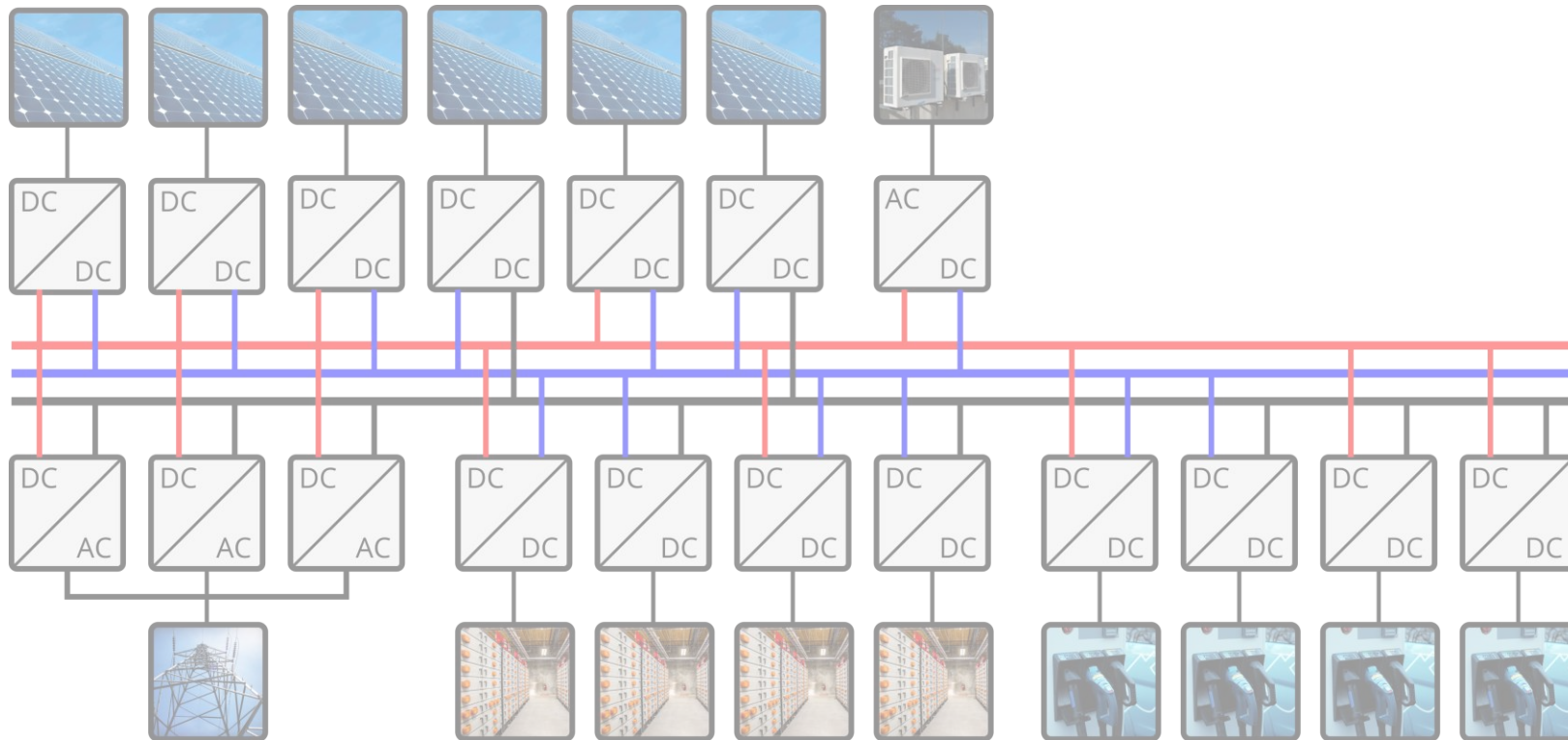


Why bipolar LVDC?

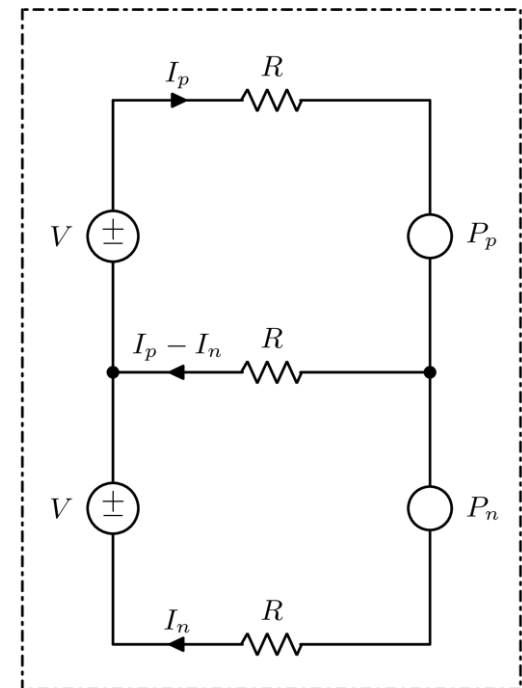
A practical example



How to keep the pole-to-neutral voltages balanced?

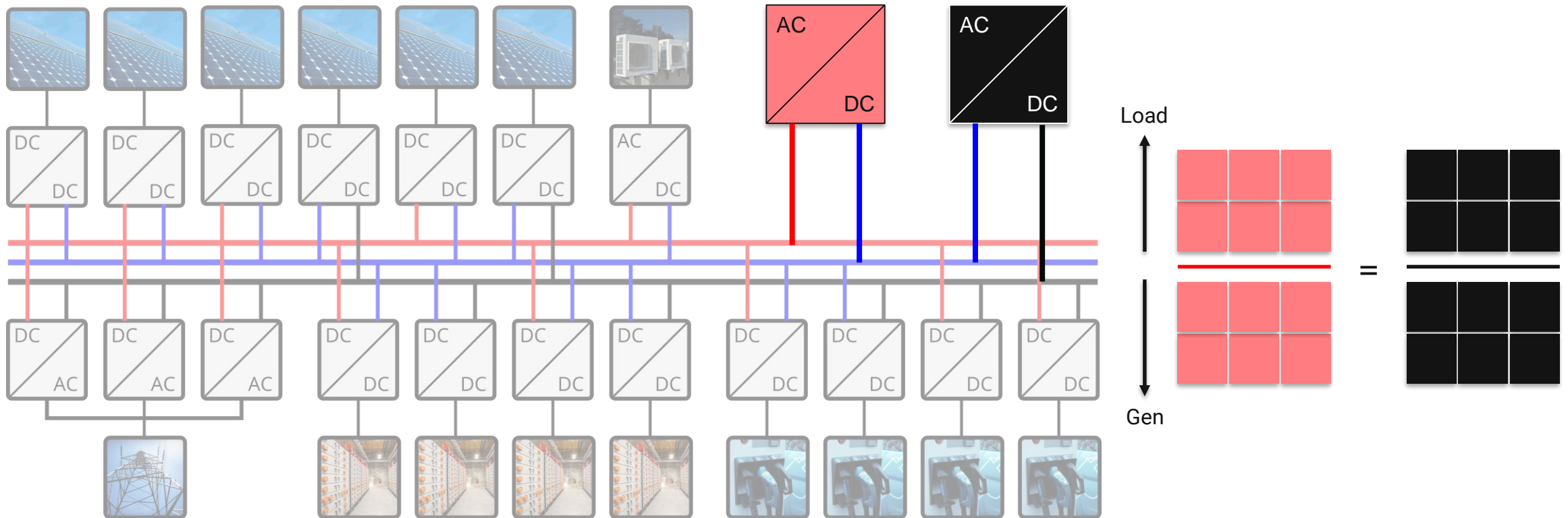


Bipolar network



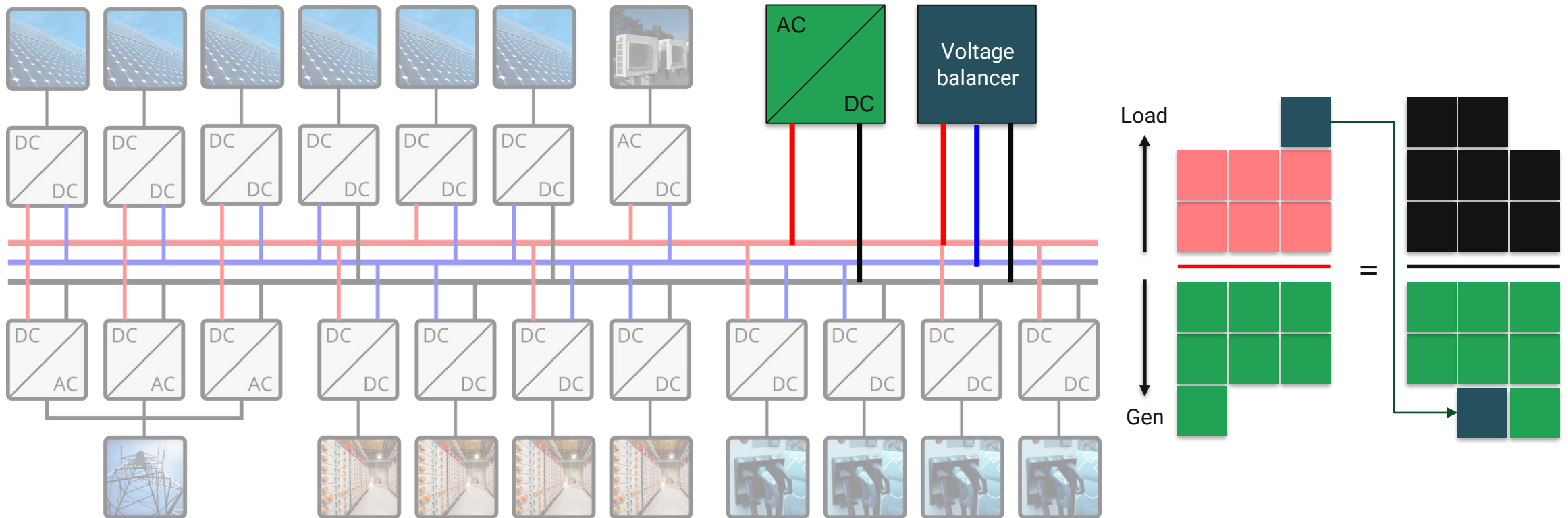
How to keep the pole-to-neutral voltages balanced?

Option 1 - Two stacked AC/DC or DC/DC converters



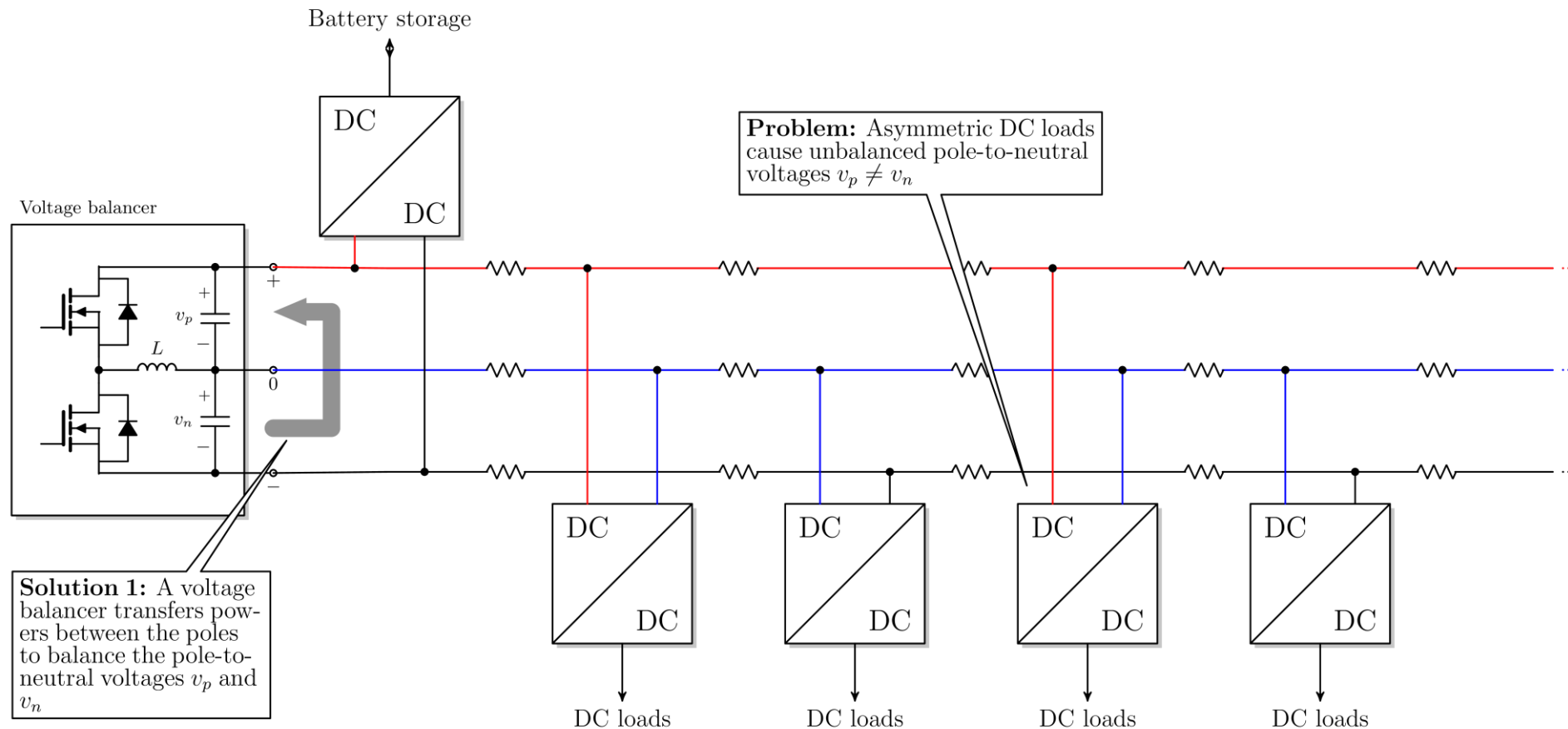
How to keep the pole-to-neutral voltages balanced?

Option 2 - A single AC/DC or DC/DC converter and voltage balancer



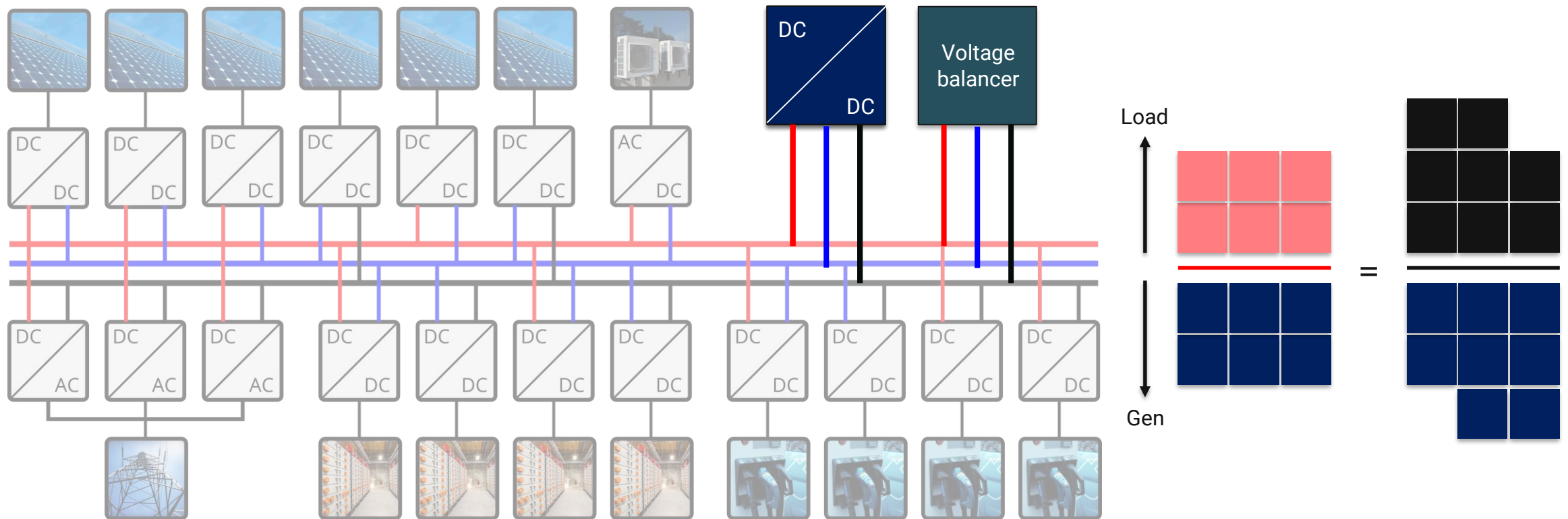
How to deal with the voltage unbalance issue?

The half-bridge voltage balancer transfers power



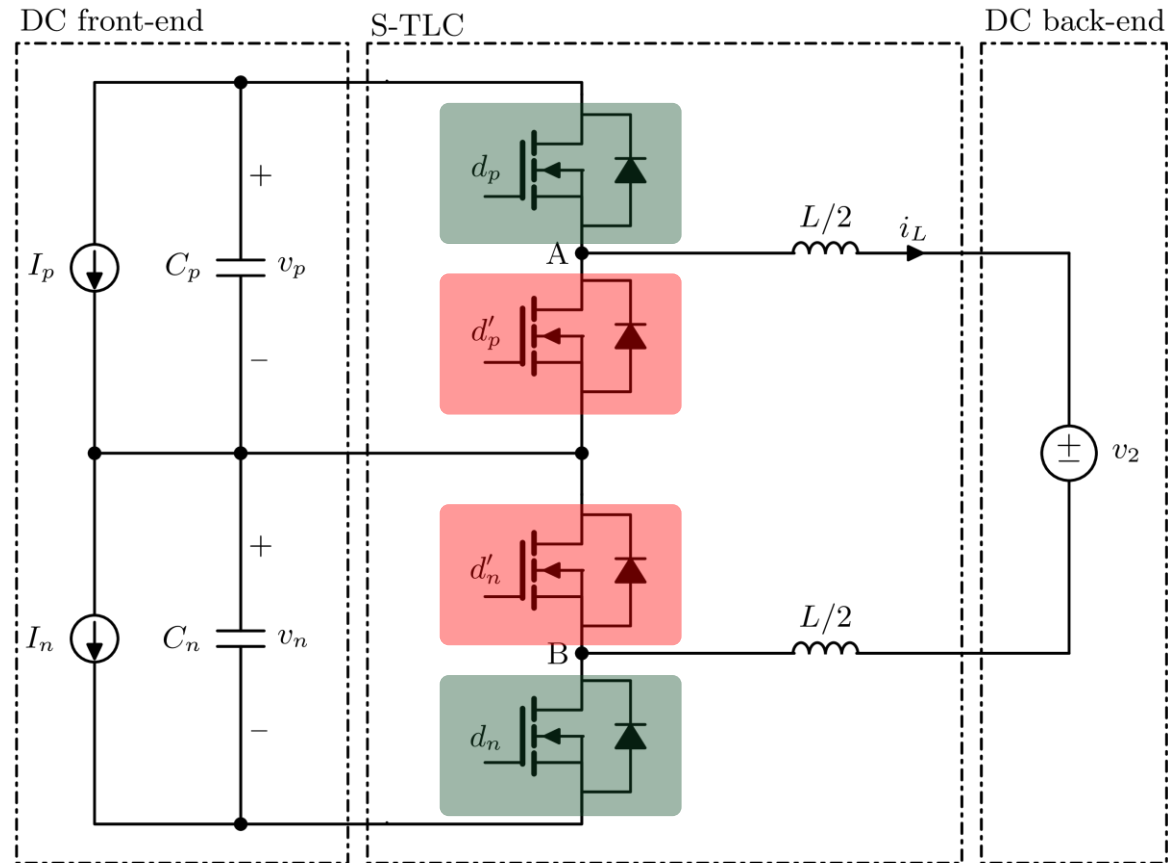
How to keep the pole-to-neutral voltages balanced?

Option 3 - A three-level DC/DC or AC/DC converter



Operation of three-level DC-DC converters

Conversion stage 1



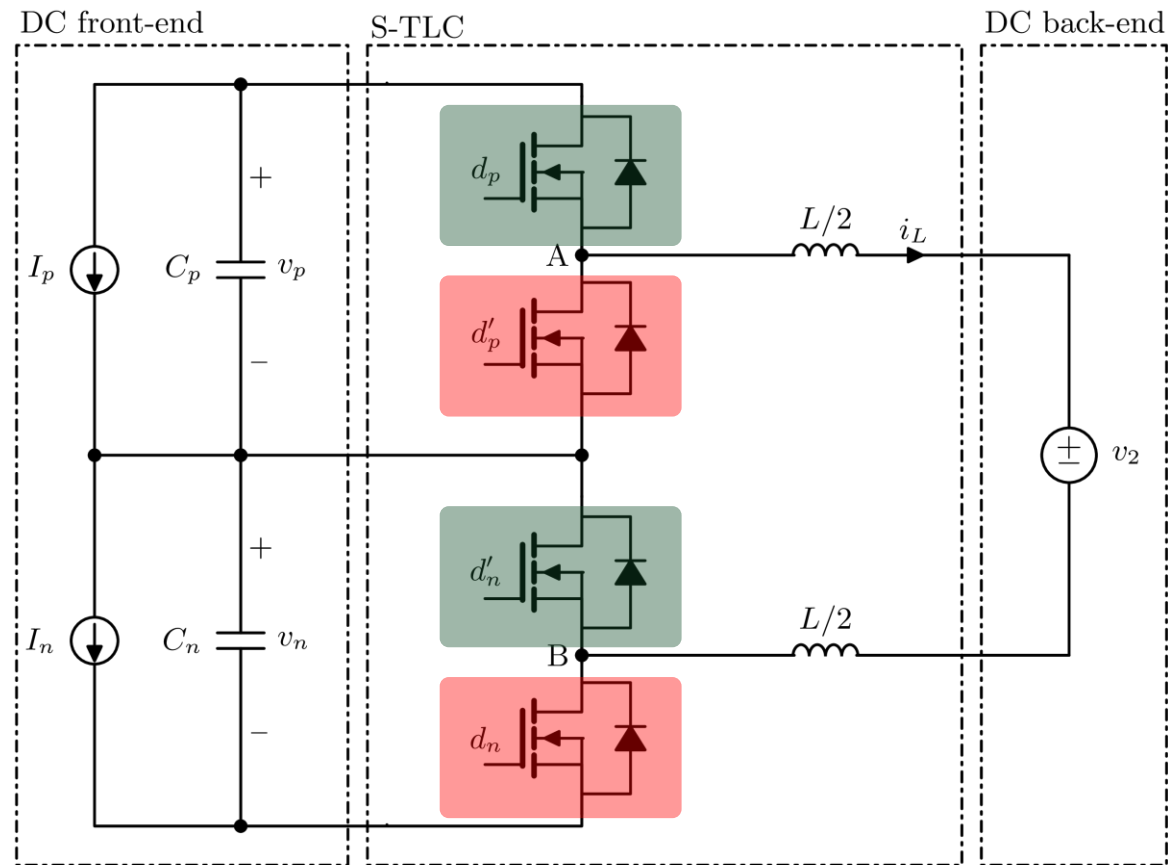
Battery storage



Solar photovoltaics

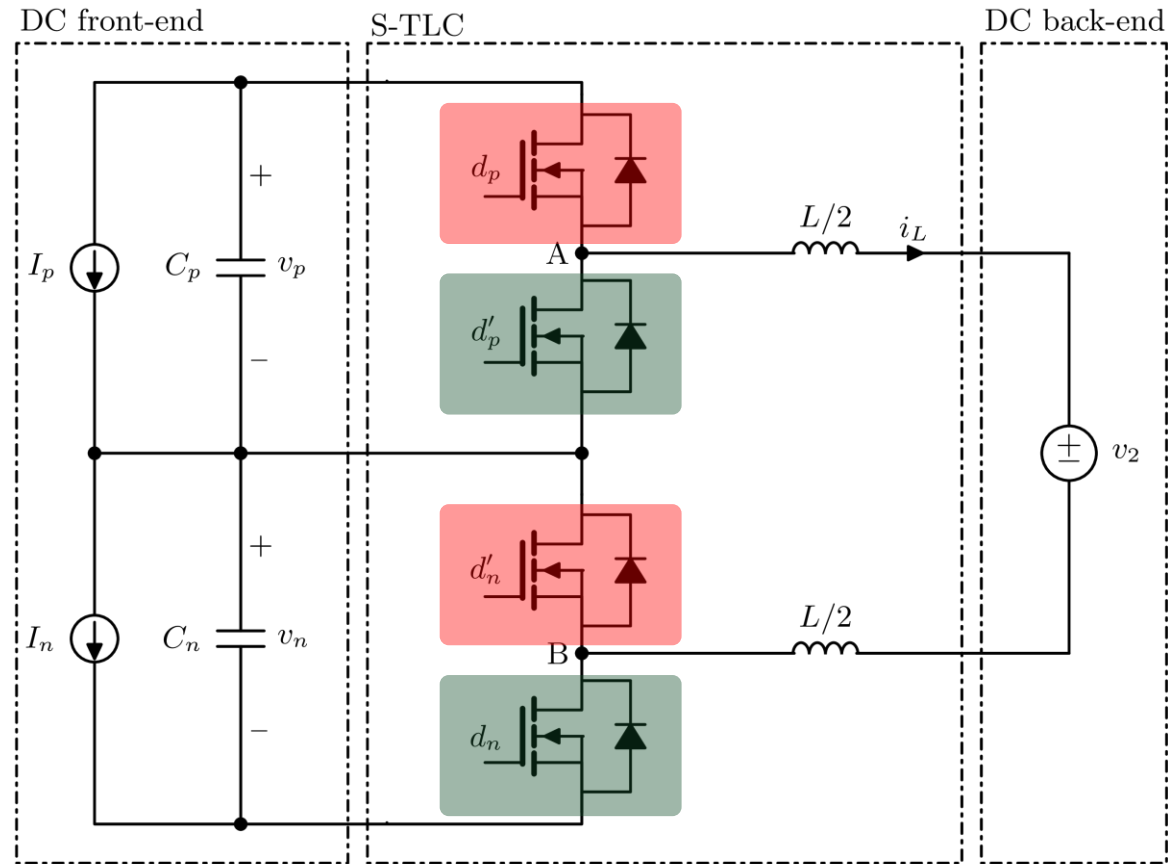
Operation of three-level DC-DC converters

Conversion stage 2



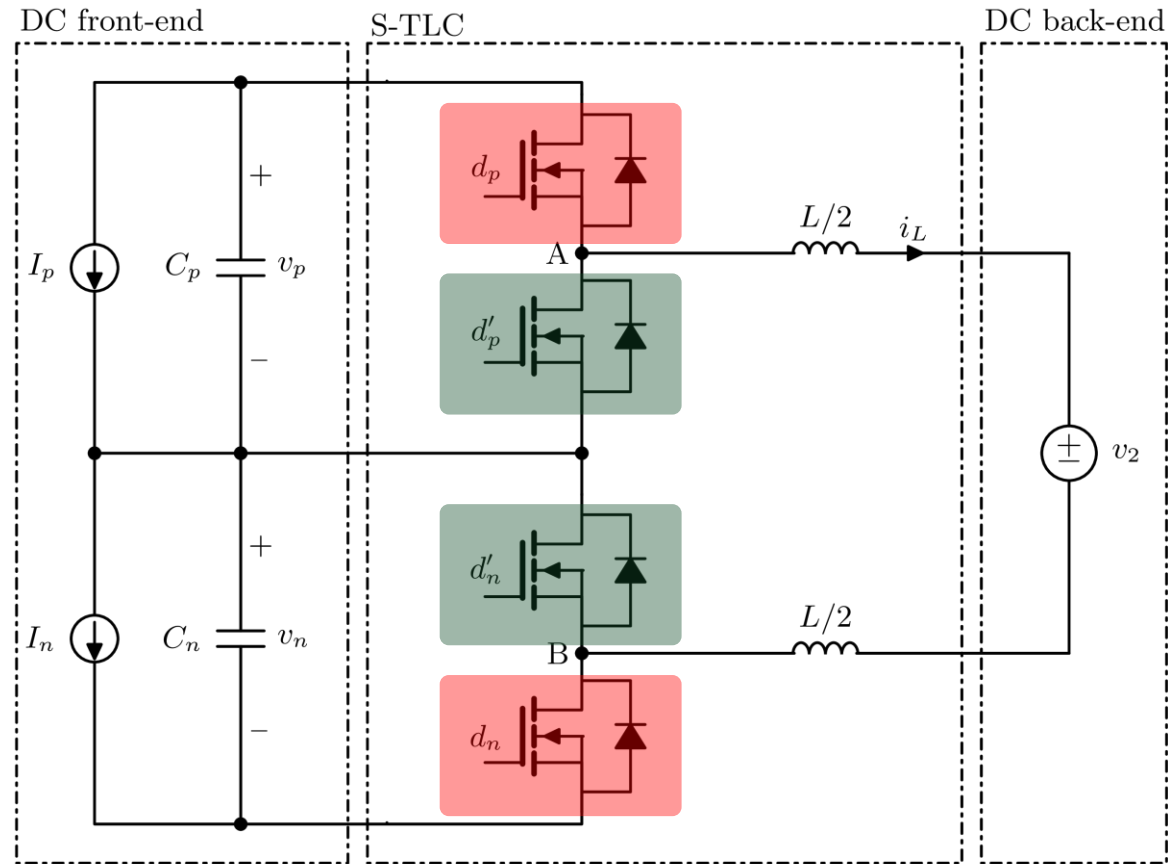
Operation of three-level DC-DC converters

Conversion stage 3



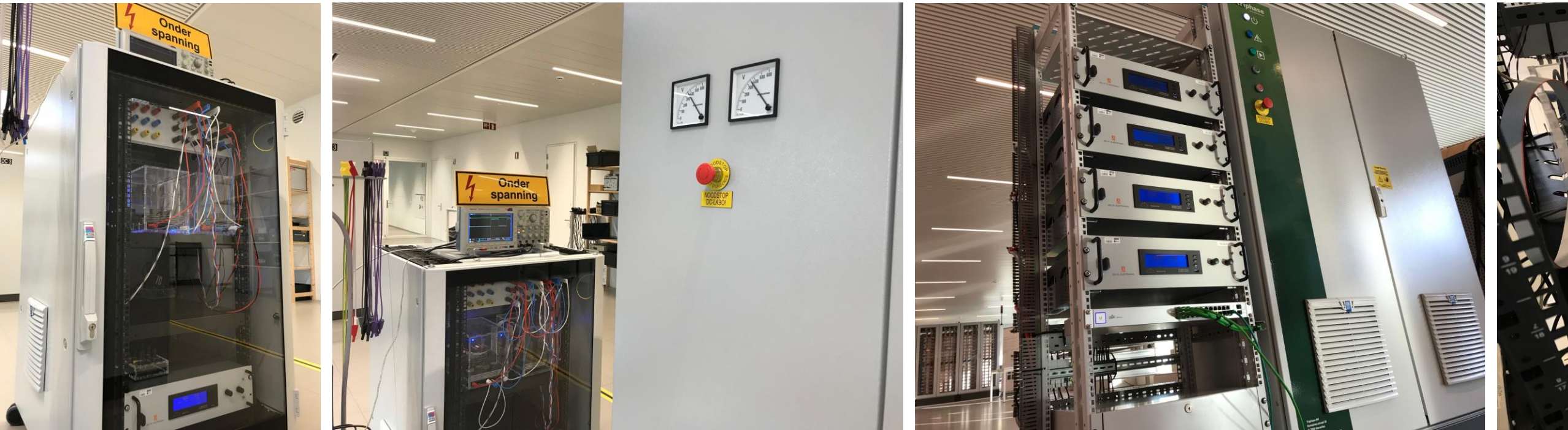
Operation of three-level DC-DC converters

Conversion stage 4



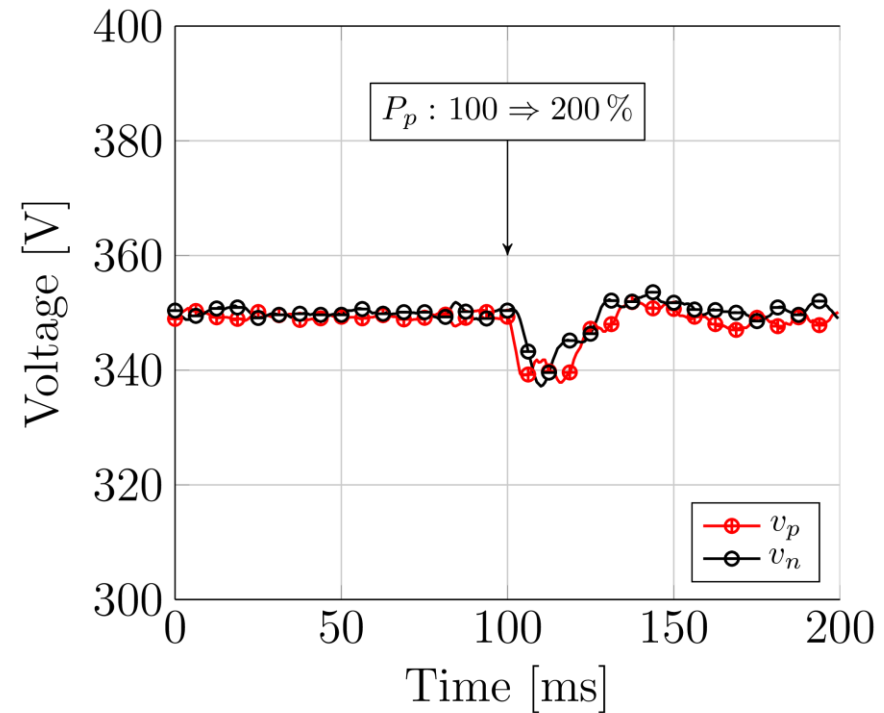
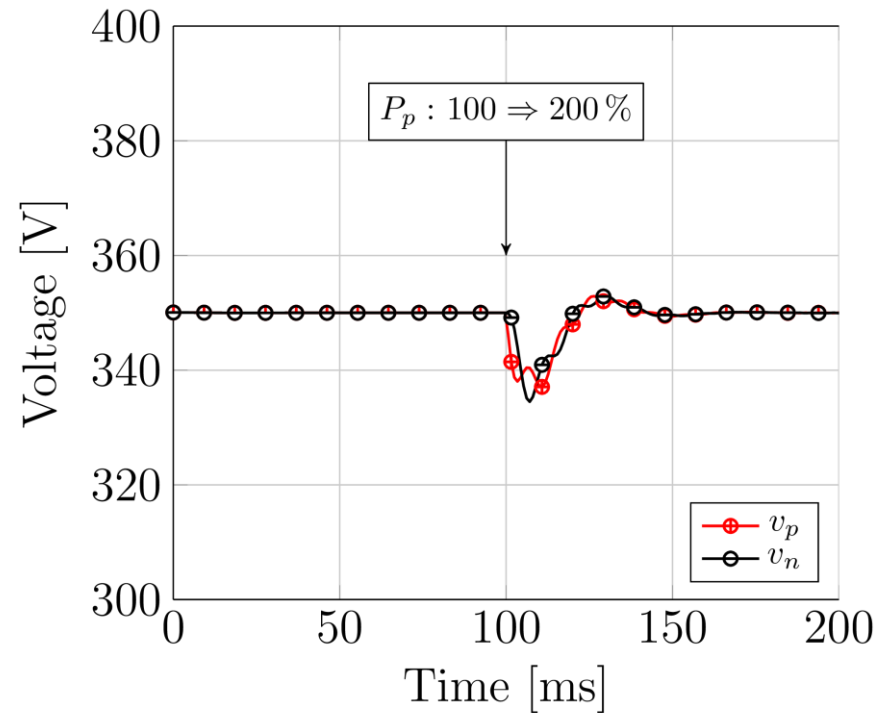
Three-level DC-DC converters

DC/DC converters and controllers developed in the EnergyVille LVDC lab



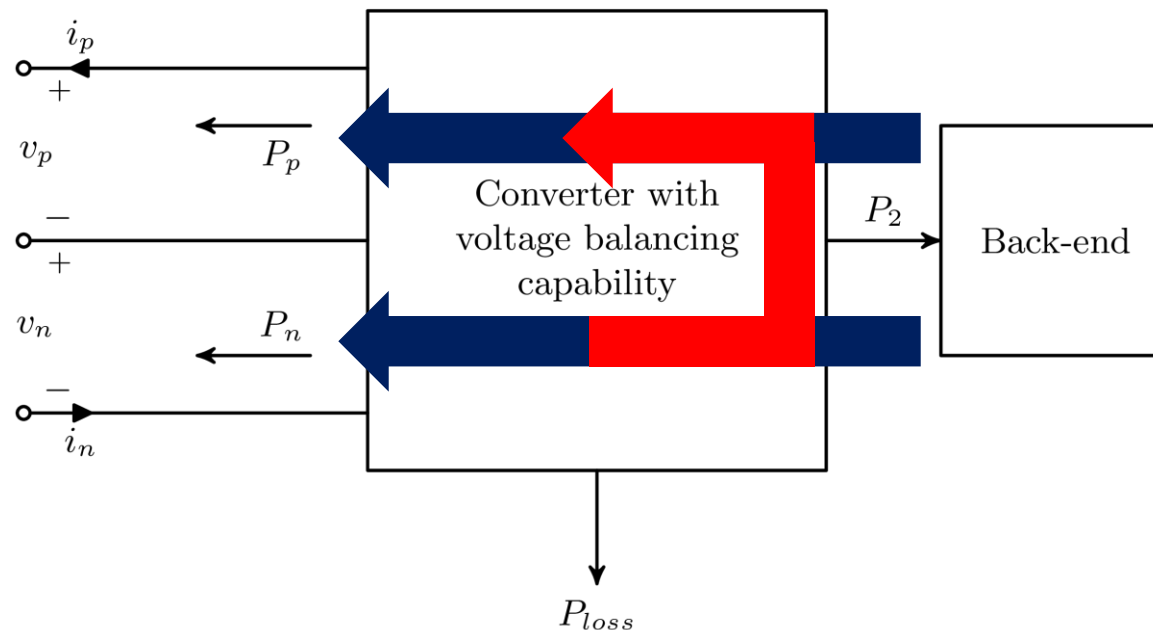
Three-level DC-DC converters

DC/DC converters and controllers developed in the EnergyVille LVDC lab



Definition of the conversion efficiency

The balanced and unbalanced conversion efficiency



$$P_b = \frac{P_p + P_n}{2} \quad \leftarrow$$

$$P_u = \frac{P_p - P_n}{2} \quad \leftarrow$$

$$P_{loss,b} \equiv P_{loss} |_{P_u=0}$$

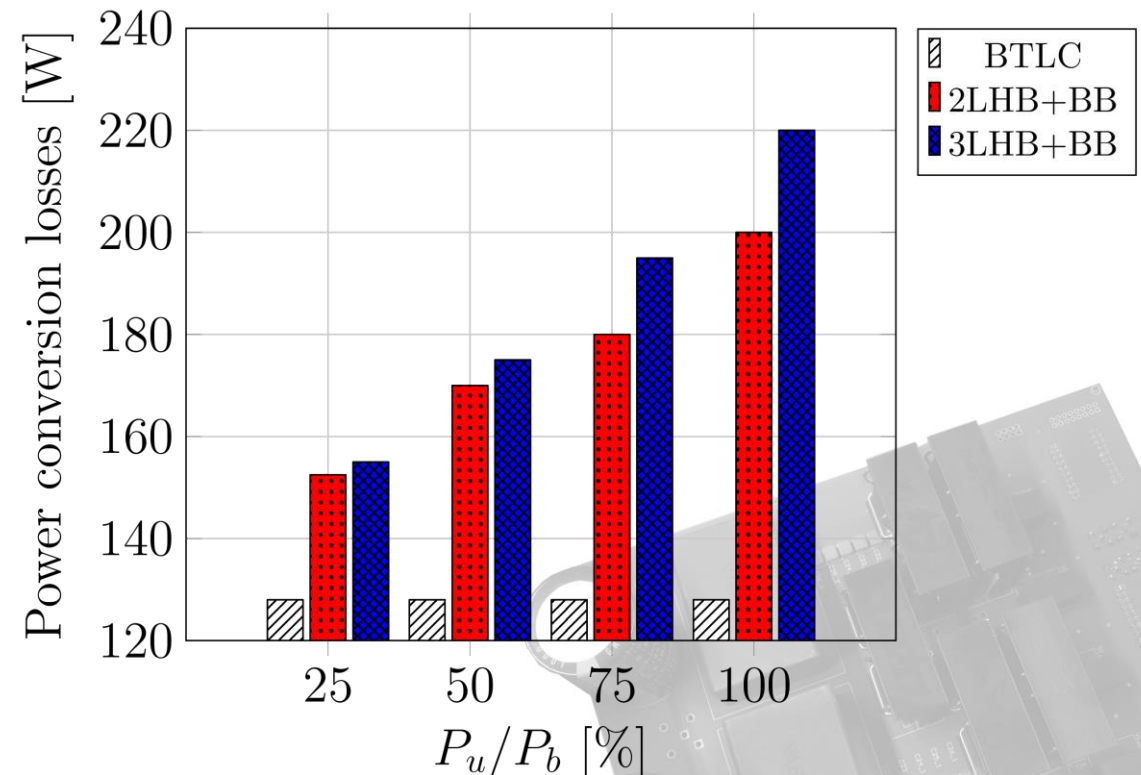
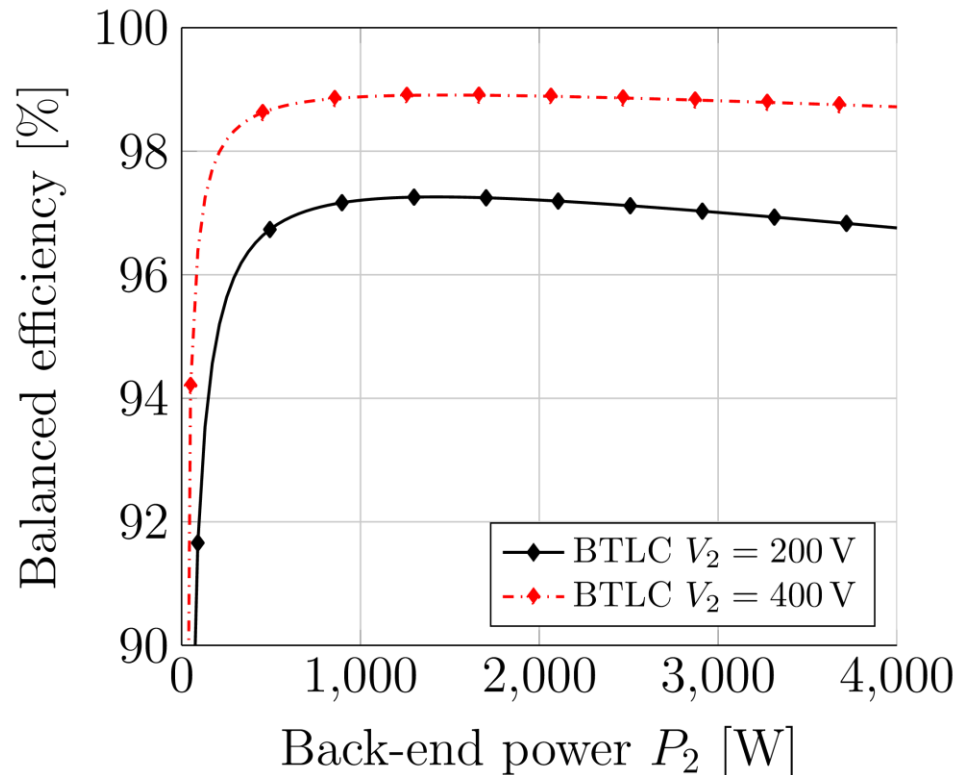
$$P_{loss,u} = P_{loss} - P_{loss,b}$$

$$\eta_b = \begin{cases} 1 + \frac{P_{loss,b}}{2P_b} & \text{if } P_2 \geq 0 \\ 1 + \frac{P_{loss,b}}{P_2} & \text{if } P_2 < 0 \end{cases}$$

$$\eta_u = 1 - \frac{P_{loss,u}}{|P_u|}$$

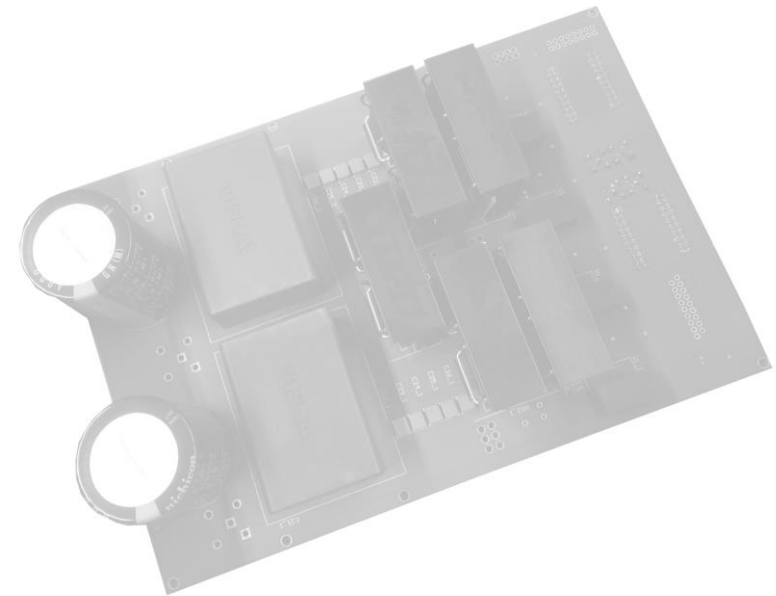
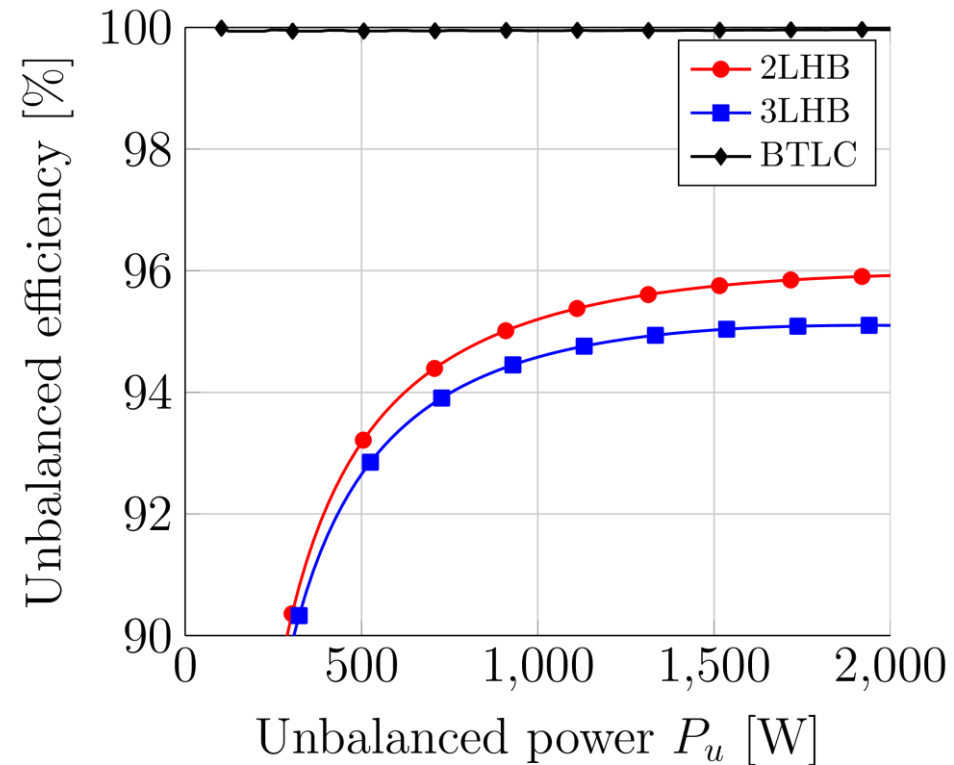
What is the impact on the conversion efficiency?

Direct balancing has a positive impact on the conversion efficiency



What is the impact on the conversion efficiency?

The studied three-level DC-DC converter reaches 100% unbalanced efficiency



Conclusions

- Why Bipolar LVDC?
 - Increased power transfer capability
 - Two voltage levels available
- But: voltage balancing converters required
 - Direct balancing versus indirect voltage balancing
- Direct balancing has a positive impact on the conversion efficiency
- DC/DC converters and controllers developed in the EnergyVille LVDC lab