EPE '22 ECCE EUROPE
September 5-9, 2022
Hannover, Germany
Institute for Drive Systems and Power Electronics
Leibniz Universität Hannover
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# Triple-Phase-Shift Controlled Dual Active Bridge Converter with Variable Input Voltage in Auxiliary Railway Supply

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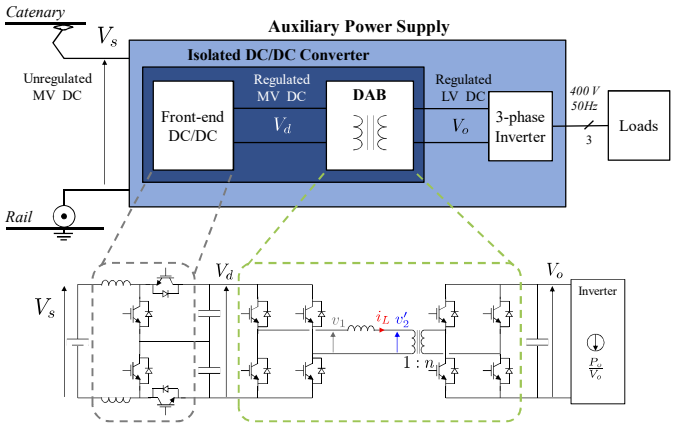
Auxiliary Railway Supply converts the electric power of the catenary into consumer-orientated power for equipment's such as air conditioning, lighting, battery charging, etc.

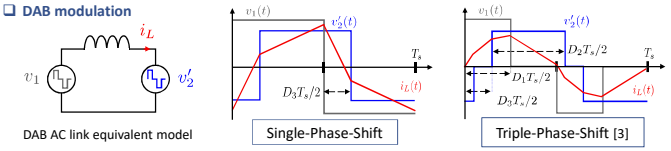
High power density, bidirectional power flow and galvanic isolation are required. Dual Active Bridge (DAB) with a simple Single-Phase-Shift (SPS) modulation is suited as long as $V_o/V_d \approx n$ [1] else, poor efficiency and high current stress occur. Because $V_s$ is subject to wide variations [2], a front-end boost converter is used to regulate $V_d$.

**Contribution :**
Gain **weight** and **simplicity** by removing the front-end converter while **maintaining high power density.**

**Challenges :**
- ❑ DAB modulation enhancement
- ❑ Isolated converter design
- ❑ Efficiency calculation




❑ DAB modulation

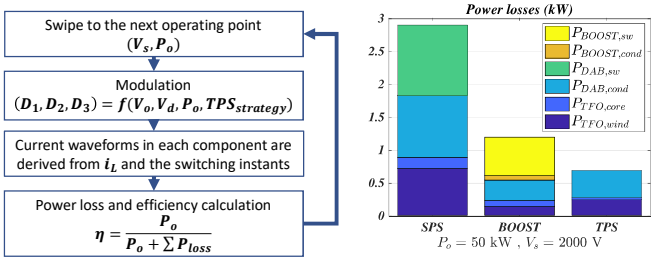



❑ **Design of a simplified Isolated DC/DC converter**

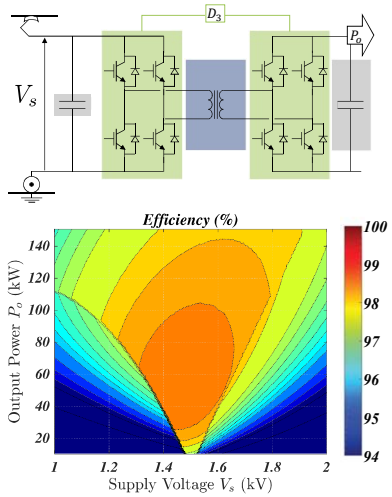
- ✓ Rated conditions : $P_{o,rated} = 150\ kW, V_{s,rated} = 1.5\ kV$
- ✓ Medium frequency transformer characteristics are obtained using the Area product method.
- ✓ Switching elements are chosen based on industrial available products.

| | With boost converter | Without boost converter |
|---|---|---|
| Output Power Range $P_o$ | 10 ~ 150 kW | 10 ~ 150 kW |
| Supply dc voltage $V_s$ | 1 ~ 2 kV | 1 ~ 2 kV |
| DAB Input dc voltage $V_d$ | 2 kV | 1 ~ 2 kV |
| DAB Output dc voltage $V_o$ | 750 V | 750 V |
| Switching frequency | 5 kHz | 5 kHz |
| Transformer Turns Ratio $n$ | 3/8 | 1/2 |
| Primary side max rms Current | 91 A | 167 A |
| Mass of the transformer | **70 kg** | **111 kg** |
| Output Capacitor max rms Current | **88 A** | **167 A** |

❑ **Efficiency calculation for every operating condition**

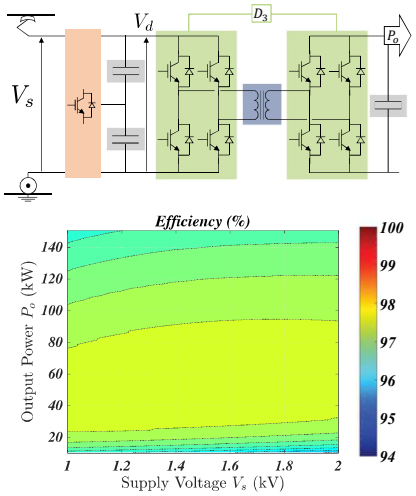



## SPS Control with Unregulated Voltage Supply



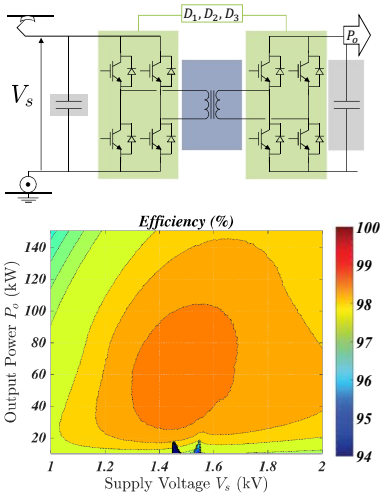

- ✓ Control complexity ↓
- × High current stress
- × Soft switching condition is lost
- × Weight and volume of passive components ↑

## SPS Control with Regulated Voltage Supply




- ✓ No sensitivity to supply voltage variation
- ✓ SPS modulation
- × Losses at rated conditions ↑
- × Front-end converter regulation

## TPS Control with Unregulated Voltage Supply




- ✓ Efficiency in severe conditions ↑
- ✓ Number of parts ↓
- × Weight and volume of passive components ↑
- × Modulation complexity ↑

**Acknowledgment**
The authors would like to thank C. Versèle, Alstom Belgium, for supporting this work.

**References**

[1] Krismer, Florian. "Modeling and optimization of bidirectional dual active bridge DC-DC converter topologies."(2010). [2] BS EN 50163 Railway applications. Supply voltages of traction systems
[3] S. Shao, M. Jiang, W. Ye, Y. Li, J. Zhang and K. Sheng, "Optimal Phase-Shift Control to Minimize Reactive Power for a Dual Active Bridge DC–DC Converter," in IEEE Transactions on Power Electronics, vol. 34, no. 10, pp. 10193-10205, Oct. 2019