Educational hardware trainer for teaching the Dual Active Bridge in a DC Grid.

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Introduction

Task: Teaching the application of the Dual Active Bridge using a Hardware Trainer

- Dual Active Bridge [DAB]
- Topology and Modulation
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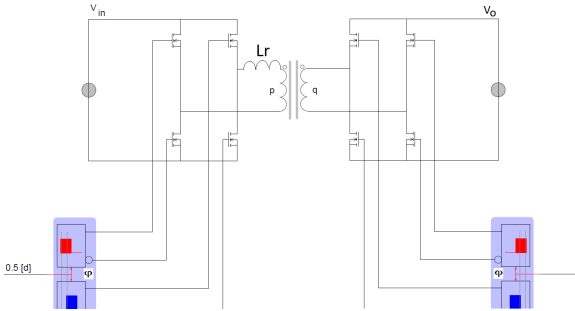
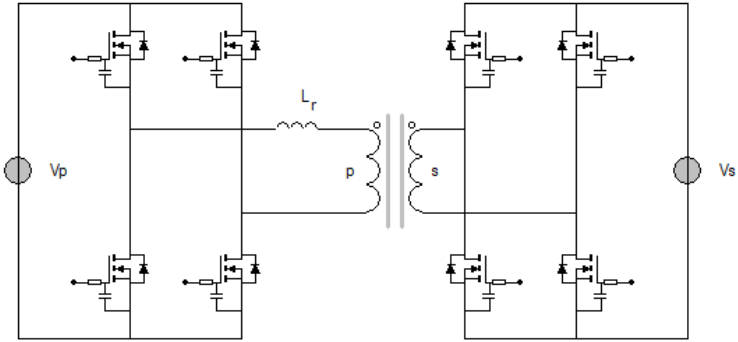
- Hardware Trainer

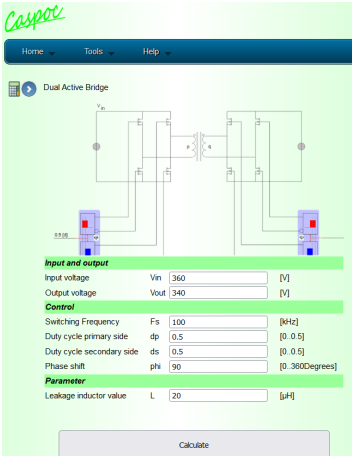


Dual Active Bridge



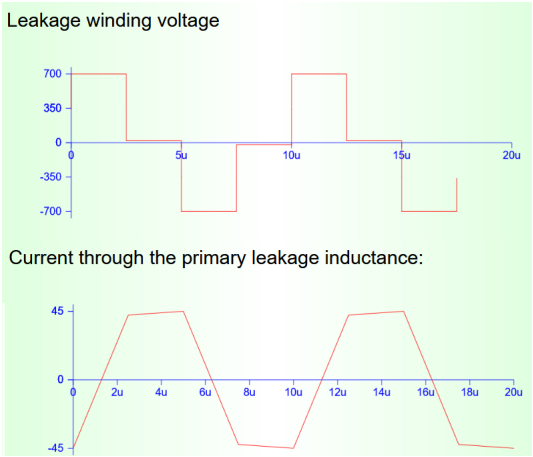
Dual Active Bridge with leakage inductance shown next to the coupled inductors.

Online Design Tool



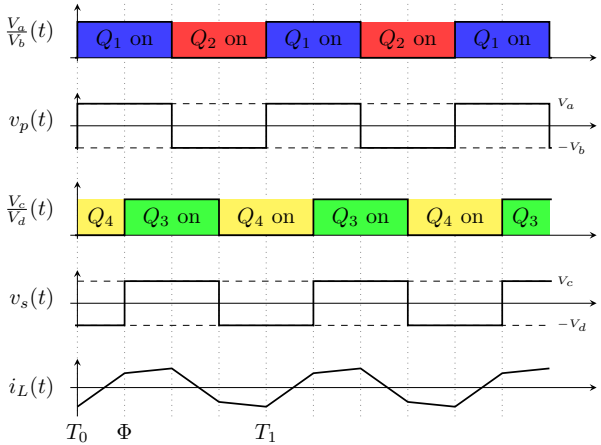
Design tool to calculate the current waveform and power transfer.

Online Design Tool



Voltage across and current through the leakage inductor L_r.

Principle of Operation



Phase-shift modulation, showing the Mosfet state, Bridge voltages and current through the leakage inductor L_r.

Principle of Operation

$$P_{Nom} \propto \frac{V_{max}^2}{F_s \cdot L_{Leakage}} \tag{1}$$

$$i_0 = \frac{T_s}{2L_r}\left(-\frac{V_{in}}{2} + \frac{nV_o}{2} - nV_o\frac{\varphi}{\pi}\right) \tag{2}$$

$$i_\varphi = \frac{T_s}{2L_r}\left(-\frac{V_{in}}{2} + \frac{nV_o}{2} + V_{in}\frac{\varphi}{\pi}\right) \tag{3}$$

$$i_\pi = \frac{T_s}{2L_r}\left(\frac{V_{in}}{2} - \frac{nV_o}{2} + nV_o\frac{\varphi}{\pi}\right) \tag{4}$$

$$P_o = \frac{nV_{in}V_o}{2f_sL_r}\frac{\varphi}{\pi}(1 - \frac{\varphi}{\pi}) \tag{5}$$

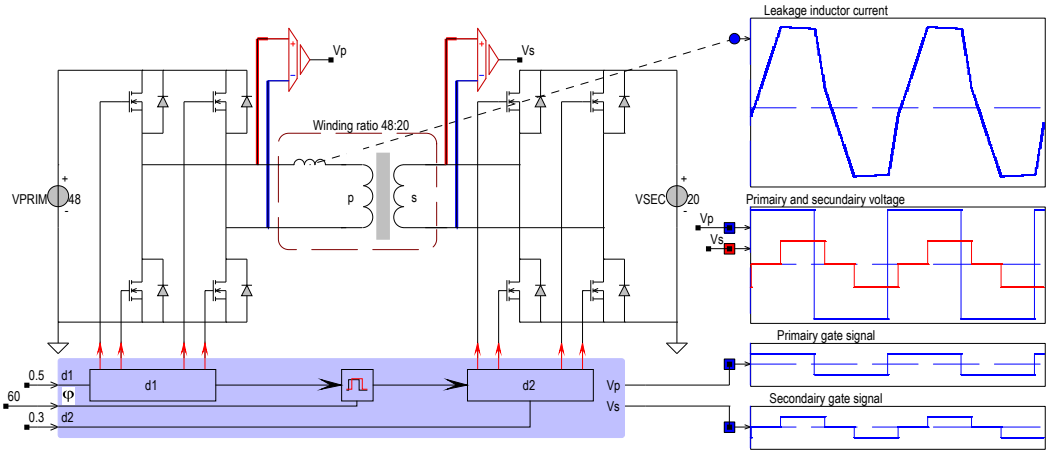
Calculated Values

Pin=7.65[kW] Tp2=5[µs] Tp3=5[µs] Tp4=10[µs] Ts1=2.5[µs] Ts2=2.5[µs]
Ts3=7.5[µs] Ts4=7.5[µs] Ts5=10[µs]

t=	0µs	0µs	2.5µs	2.501µs	5µs	5.001µs	7.5µs	7.501µs	10µs	10µs
V_L=	340V	700V	360V	20V	-340V	-700V	-360V	-20V	340V	340V
I_L=	-44.991A	-44.983A	42.483A	42.501A	45A	44.983A	-42.483A	-42.501A	-45A	-44.991A
I_{in}=	0A	-44.983A	42.483A	42.501A	45A	-44.983A	42.483A	42.501A	45A	0A

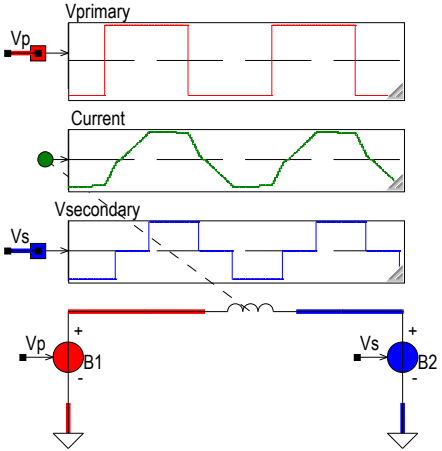
Calculated current maxima and power transfer.

Full Simulation Model



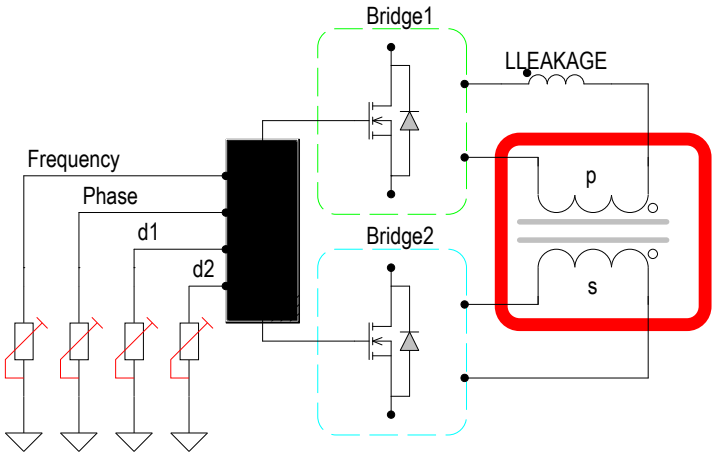
Simulation in Caspoc, of a DAB using two full bridges. The scope show from top to bottom, leakage inductor current, primary and secondary transformer voltages and left and right bridge gate signal.

Simplified Simulation Model



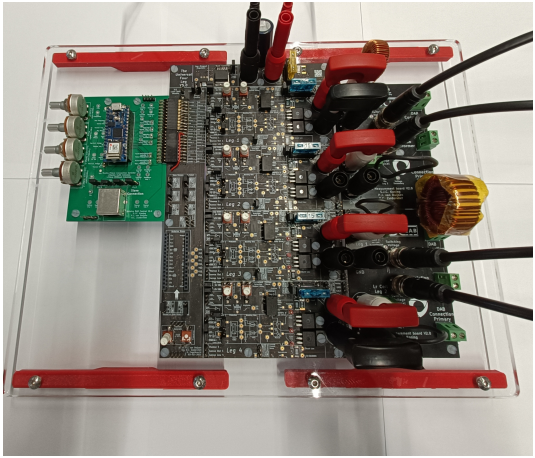
Simplified model in Caspoc, containing the two bridge voltages as controlled voltage sources coupled by only the leakage inductor L_r.

Principle Diagram



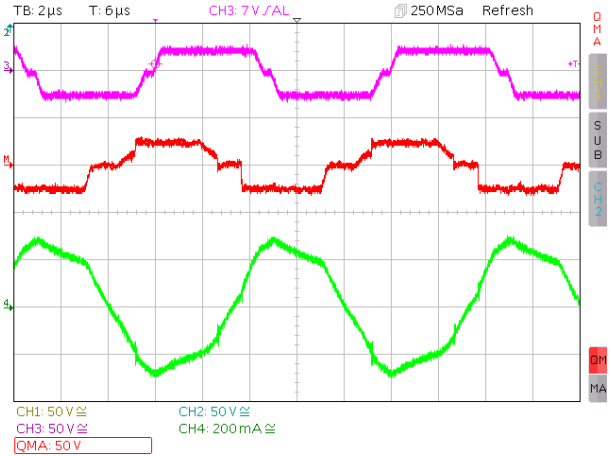
Principle schematic of the low voltage hardware trainer for the DAB, with manual controls for frequency, phase-shift and duty-cycles.

Experimental Demonstrator



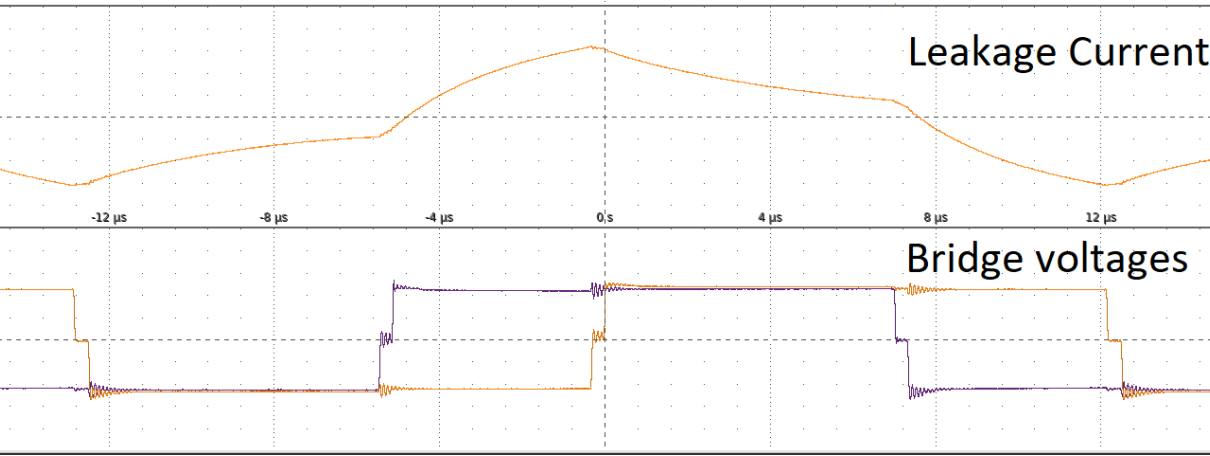
Low voltage hardware trainer, where switching frequency, duty cycles and phase shift can be manually changed by the student during operation of the DAB. Voltages across and current through the transformer can be measured with the coaxial cables.

Experimental Demonstrator



Lower trace, leakage inductor current (Ipp=1.0 Ampere), and bridge output voltages(Vpp=48v), of the DAB with phase difference of 45 degrees, operating at 100kHz, Vdc=24v.

Experimental Demonstrator



Measurement of full power transfer for $\varphi = 75°$. From top to bottom: Leakage inductor current[Ch5-Orange, $5A/div$, $4\mu s/div$] and primary[Math1-Orange] and secondary[Math2-Purple] transformer voltage[$50V/div$, $4\mu s/div$].

Conclusion

- Dual Active Bridge functionality
- Modulation
- Design tools and Simulation
- Hardware Trainer

Thank you!
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