High-Bandwidth Impedance Measurement of DC Grids Using Dual-Active Bridge Converters

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DC Grid Impedance Measurement

- Stability of multi-terminal dc systems can be determine based on system impedance, enabling black box models
- Maximum length binary sequences (MLBS) injected by a converter are used as perturbations for impedance measurement [1]

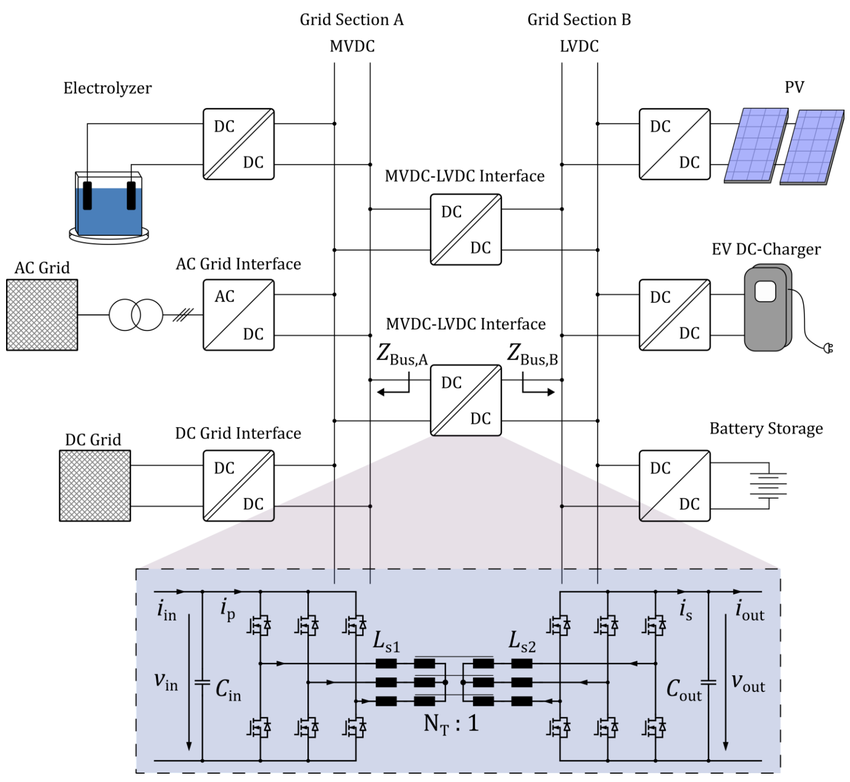

Fig. 1: Multi-bus dc system containing DAB3.

- Literature assumes buck or boost converters and direct modulation of perturbation signal onto duty cycle, resulting in non-ideal current spectrum
  - Injecting converter is typically assumed to be of very high bandwidth, e.g. ten times higher than other converters

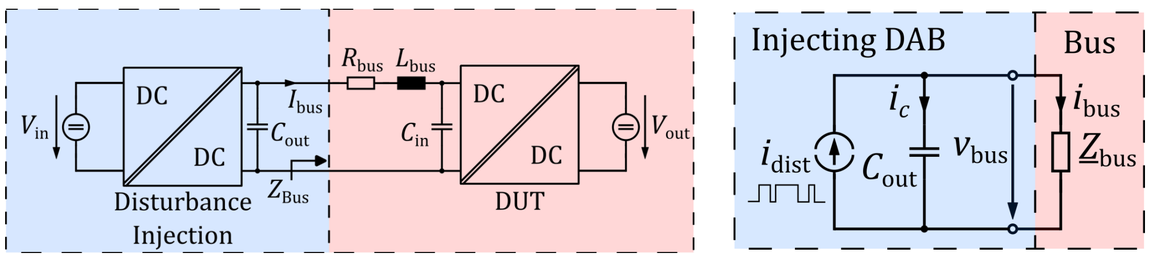

Fig. 2: Schematic and simplified model of impedance measurement using DAB3.

Disturbance Injection Using DAB3

- Use of existing converters instead of specific additional converter
- Instantaneous current control [2] allows MLBS generation bandwidth up to $2 \cdot f_{sw}$ with model-based control
  - $\varphi_{ref} = \frac{2\pi}{3} - \sqrt{\frac{4\pi^2}{9} - \frac{2\pi X_s I_{ref}}{V_{in} N_T}}$
- MLBS is pre-calculated for each switching period

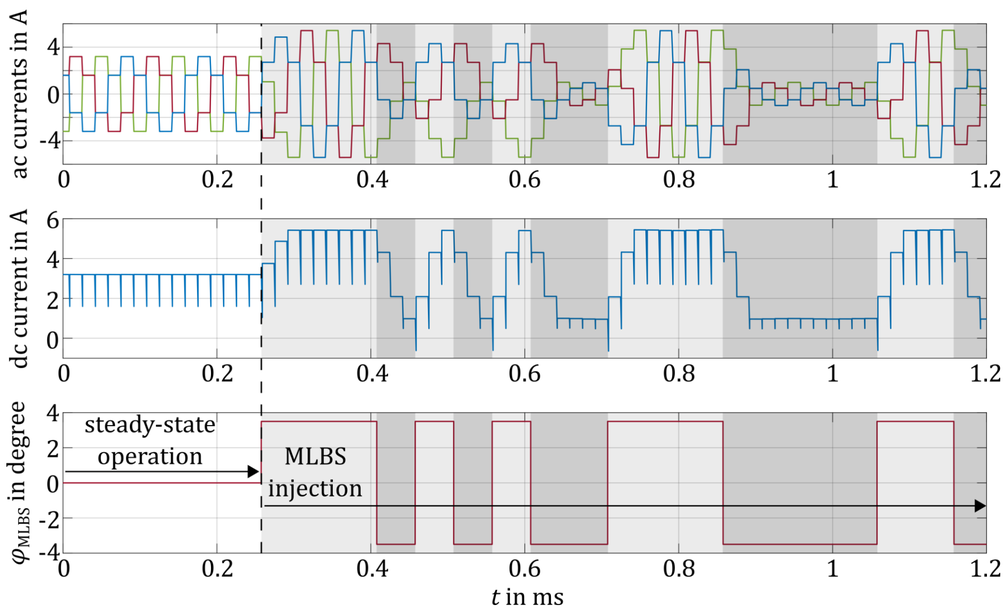

Fig. 3: MLBS and DAB3 ac and dc currents under disturbance injection.

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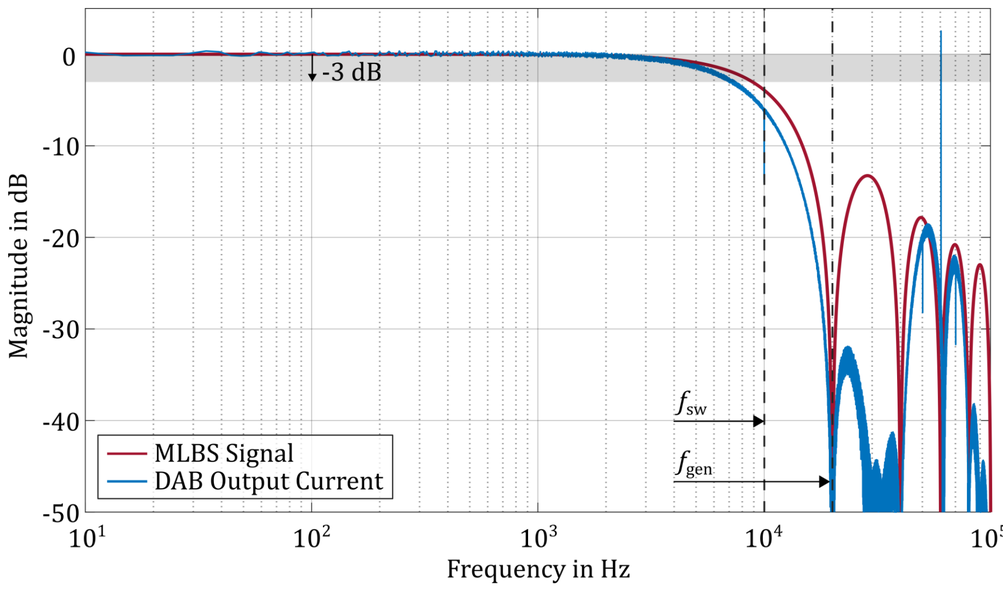

Fig. 4: Ideal MLBS spectrum and resulting DAB3 output current.

- Resulting perturbation current bandwidth: $0.7 \cdot f_{sw}$
- Ratio of output capacitance to DUT impedance needs to be considered in practical application
  - Resulting bus current $i_{bus} = \frac{i_{dist}}{1+Z_{bus}/Z_{out}}$
- Depending on application scenario, adjustment of perturbation spectrum or output dc link capacitor may be required

Experimental Verification

- Two DABs set up according to Fig. 2, DUT operates in voltage control
- Injecting DAB provides large-signal operating point and performs MLBS injection

Parameter	Injecting DAB3	DUT
Input voltage V_{in}	120 V	120 V
Output voltage V_{out}	120 V	120 V
Transformer winding ratio N_T	1	1
Transformer series inductance L_s	25 µH	25 µH
Switching frequency f_{sw}	10 kHz	30 kHz
Dc link capacitance C_{in}, C_{out}	122 µF	122 µF
MLBS generation frequency f_{gen}	20 kHz	N.A.

Table 1: Evaluation parameters

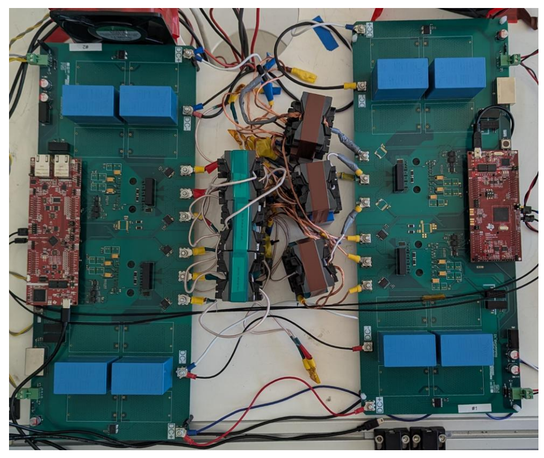

Fig. 5: Experimental setup.

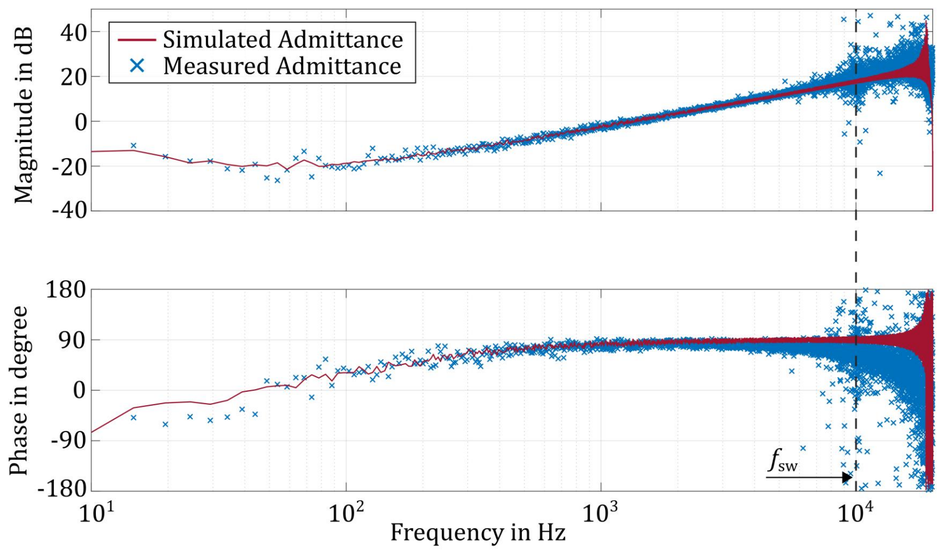

Fig. 6: Simulated and measured admittance of voltage controlled DAB.

Conclusions

- Proposed disturbance injection for DAB3 allows high-bandwidth impedance measurements of dc systems and converters
- Future work: evaluation in larger dc systems, improvements of impedance measurement

References:

[1] T. Roinila, M. Vilkko and J. Sun, "Broadband methods for online grid impedance measurement," 2013 IEEE Energy Conversion Congress and Exposition, Denver, CO, USA, 2013, pp. 3003-3010.
[2] S. P. Engel, N. Soltau, H. Stagge and R. W. De Doncker, "Dynamic and Balanced Control of Three-Phase High-Power Dual-Active Bridge DC–DC Converters in DC-Grid Applications," in IEEE Transactions on Power Electronics, vol. 28, no. 4, pp. 1880-1889, April 2013.