Dynamic analysis and control of a multi-cellular DC/DC converter

PhD thesis

Keywords:

Power electronics, DC/DC converters, GaN components, high frequency, dynamic modeling, real-time control.

Context:

Climate change is one of the most important global issues of our time. The world aviation industry has set a goal of reducing carbon dioxide emissions by 50% by 2050 compared to 2005. More electric or even fully electric aircraft are being developed to achieve this goal. Multiplying the number of electrical systems on board aircraft leads to a significant increase in the need for non-propulsive power. The voltage of the distribution networks will be raised to 270 VDC, 540 VDC or even 800 VDC in order to meet this evolution. Only some critical equipment such as calculators or injectors will continue to be supplied with 28 VDC.

The design of the 800 VDC and 28 VDC network interconnections is a big challenge for aeronautical equipment manufacturers like Safran. The use of new types of components (e.g. Wide Bang Gap) and modern converter topologies (e.g. Dual Active Bridge) could allow excellent power densities. Recent work conducted jointly by GeePs and Safran has demonstrated a power density of 4kW/kg for a Dual Active Bridge 270 VDC / 28 VDC converter using GaN components [1] (see Figure 1 and 2).

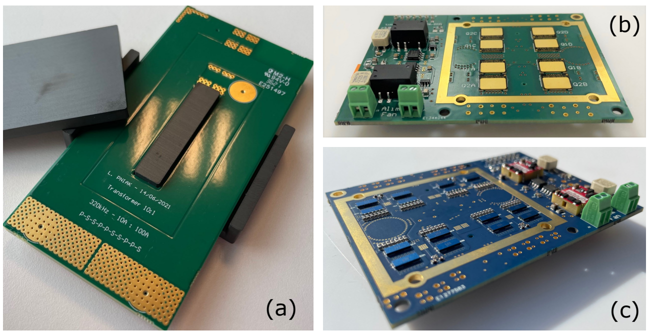
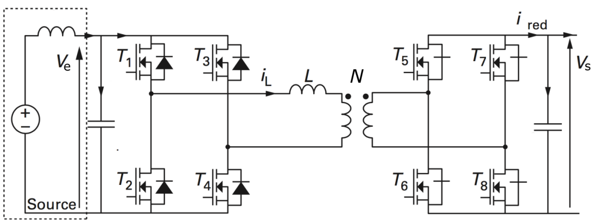


Figure 1 – Main elements of the Dual Active Bridge: (a) Transformer, (b) HV bridge, (c) LV bridge.



Parameter	Nominal value	Range of variation
Input voltage V_e	270 V	[210;330] V
Output voltage V_s	28 V	[16;32] V
Nominal power P	to be determined between 1 and 3 KW	

Figure 2 – Electrical schematics of the Dual Active Bridge and its specifications.

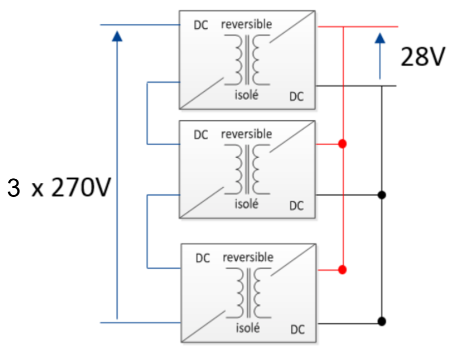


Figure 3 – Input series and output parallel association of the elementary converter.

Objectives:

The challenge of this work is to develop a DC/DC converter 800V DC / 28 VDC whose power can reach a few tens of kilowatts, and this from the optimized elementary converter 270 DC / 28 VDC already developed within our teams. These converters will be associated in series and in parallel to respectively reach the desired voltage and power levels (see Figure 3). This work will consist in proposing a control strategy for the elementary converters [2] and for their association, the objective being to minimize the overall losses and the EMI filters mass in the global converter for all operating conditions [3].

Detailed assignments:

The work can be organized in the following way:

1. **state of the art** on the dynamic modeling of power electronics structures, on the control strategies of Dual Active Bridge and modular converters,
2. **dynamic modeling** of the Dual Active Bridge and the modular converter,
3. from this dynamic modeling, **proposing an optimal control strategy** for the multicellular converter guaranteeing the minimization of losses and EMI filters mass for all operating points, different filter architectures will be considered,
4. **implementation** of the control strategy on a microcontroller or FPGA and **experimental tests**,
5. **writing of the PhD thesis**,

Candidate profile :

The candidate must demonstrate a strong interest in power electronics and be comfortable with the concepts of system dynamics and system control. Curiosity, autonomy and initiative are highly valued qualities.

Additional information :

GeePs supervisors : Adrien Voldoire, Olivier Béthoux.
Safran supervisor : Lucas Pniak.
Contact : lucas.pniak@safrangroup.com, adrien.voldoire@centralesupelec.fr, olivier.bethoux@sorbonne-universite.fr
Workplace : GeePs laboratory & Safran Tech

References:

[1] L. Pniak, B. Revol, L. Quéval, J.-S. Ngoua Teu Magambo and O. Béthoux, "Pre-sizing of a modular high power density DC/DC converter with GaN components" Electrimacs 2022
[2] G. Oggier, G. O. García and A. R. Oliva, "Modulation strategy to operate the dual active bridge DC-DC converter under soft switching in the whole operating range," in IEEE Transactions on Power Electronics, vol. 26, no. 4, pp. 1228-1236, April 2011, doi: 10.1109/TPEL.2010.2072966.
[3] T. H. Phung et al., "Bidirectional AC to DC Isolated Multi-Cell Converter," 2019 21st European Conference on Power Electronics and Applications (EPE '19 ECCE Europe), 2019, pp. P.1-P.9, doi: 10.23919/EPE.2019.8915568.