# Circular Economy in Power Electronic: opportunity of a modular design

**Scientific context and PhD objectives**

Power electronic converters are used for electric energy conditioning. It consists in converting voltage and current electrical waves together to adapt them to a given electrical load, as well as to a given electric source, while minimising the power losses and the disturbances generated. Power electronic converters are therefore massively used as supply units in a majority of electronic equipment today. Despite great efforts in reducing power losses, the electricity consumption remains a high contributor to climate change since electrical energy needs are continuously growing. The number and vest volumes of components, devices and systems are also growing accordingly despite R&D efforts. The climate roadmap presented in France in July 2017 targets carbon neutrality in 2050. Circular Economy is envisaged as a way to support the energy transition toward carbon neutrality. With the widespread use of power electronics in all equipment, it is becoming imperative to pay attention to the life cycle of these converters in a circular thinking. The complexity and diversity of the components implemented in these converters make their environmental impact analysis difficult but necessary. The application of such components in mobility, robotics, data centre (etc.) embraces a wide range of production, usage, end of life treatment systems; industrial sectors and actors. Addressing the modularity of such components to improve their circularity in products, extending their lifespans, reducing their replacement, is necessary to envisage their sustainable usage in a society constrained by energy and material resources inputs and emissions to air, water and soil. This circular life cycle study can be better envisaged by the opportunity offered by the multi-cell converter design and implementation approach proposed by G2Elab. After having designed a first generic conversion cell, based of a modular approach, the G2Elab EP team demonstrated the viability and the effectiveness of the method. Complementarily the G-Scop lab is currently leading several research programs in circular economy and integrated design approach.

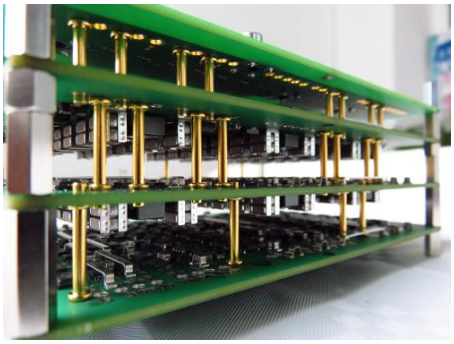

Figure 1 : the modular converter view 3,6kW

Together, the G2Elab in partnership with the G-Scop lab wish to integrate into the design of the elementary cell and its implementation, product life cycle constraints in a circular thinking and to evaluate the impact of these new constraints on converter performance.

**Scientific program**

The scientific challenge of this PhD project is to investigate a new design way leading to power converter productions from mechatronic and standardised power electronics “bricks” (i.e. integrated electronics and mechanics) with a high potential of re-circularity. The scientific issues are considerable. The main industries already in place in the power electronic domain are quite conservative. In addition the societal changes to support circular thinking are far from easy to be adopted by people. This project therefore constitutes a real opportunity to address the issue of strong sustainability within common electronic components radically differing in their design.

The following research axes will be approached during the PhD project to address this issue.

**Axis 1**: which opportunity the converter networks offers to support power electronic product based circularity and sustainability? How to operationally decline those opportunities into the current production-usage systems of some existing mechatronic products?

*Methods to be explored and to be applied: Ecodesign, Life Cycle Engineering, LCA – Life Cycle Assessment, MFA – Mass Flow Analysis, FMEA – Failure Mode and Effects Analysis, Scenario Analysis, Backasting, Disruptive Change, etc.*

Scenarios will be elaborated to address this challenge and to envisage some sustainable scenarios in current mechatronic products.

**Axis 2:** Which design specifications for a standardised power electronic brick supporting sustainable circular products?

*Methods to be explored and to be applied: Design To Environment methods (DfX); integrated EcoDesign & LCA; Cleaner Production and Energy Efficiency measurement methods and analysis, etc.*

This second axis consists in establishing the integrated design rules, guidelines (etc.) based on the proposed scenarios developed on the first axis. Component selections, production and manufacturing processes, environmental impact calculations (etc.) will have to be addressed together in an Agile design process. Operational product developments and performance measurements will be conducted to address the method and the required indicators to succeed in the scenario based circular thinking envisaged. A pragmatic case study will be developed.

**Axis 3**: Which technical tools and methods to scientifically validate the research outputs?

*Methods to be explored and to apply: Design Research Methodology (DRM); Demonstrator; Research Action & prototyping Evaluation; Hardware In the Loop (HIL) analysis, etc.*

The case study developed in the second axis will be a demonstrator to evaluate the performance of the power converter based on products and processes involved to move to a sustainable usage of such mechanic and electronic systems. The economic viability will also have to be addressed.
A quantitative and qualitative evaluation would be required to evaluate the research output from a scientific point of view (criteria used in research-action, design research methodologies, etc.).

**PhD organisation:** the previous 3 axes will be addressed by the PhD candidate over the 36 months funded project. Both labs are in the same location (1 km).

**First Year:** bibliography study & analysis opportunities offered by modular design of power electronics based on mechatronic sub-systems, in the objective to achieve sustainable production-usage scenarios.
**Second Year:** evaluation and comparison of the envisaged scenarios: systemic and multi-indicators impacts analysis. Development of a real based case study demonstrator.
**Third Year:** experimental validation on a real based case study: EPICUB maturation project application for innovative technological approaches. The maturation and scaling-up challenges will be both addressed. A generalisation of the scientific integrated multi-indicator and multi-impact method for eco-designing modular products based on power electronics technological innovations should be provided as an output to the research community.

A journal article in an A rank peer reviewed journal, as well as the participation to the results dissemination during international conferences are expected from the second year until the end of the project.

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