Circular Economy in Power Electronic: opportunity of a modular design

Scientific context and PhD objectives

The power electronic supports the electric energy. It consists in converting electronic waves together to adapt them to a given electrical load, as well as to a given electric source, while minimising the electrical losses and perturbations generated. Power electronics are therefore massively used in a majority of electronic equipment today. However, the electricity consumption is a high contributor to climate change. 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 used by these converters makes their environmental impact analysis difficult. 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 modular design and implementation approach proposed by G2Elab. After having designed a first generic conversion cell, base of this modular approach and demonstrated the viability of the method, the G2Elab EP team. Complementarily the G-Scop Laboratory is currently leading some research programs in circular economy in integrated design approach.

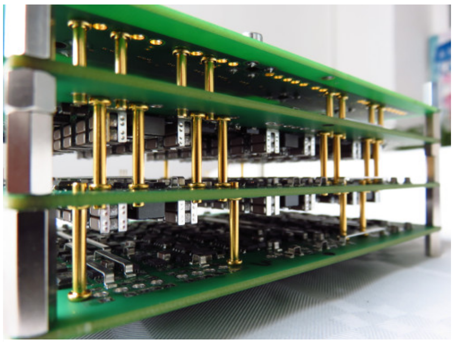

Figure 1 : the modular converter view 3,6kW

The G2Elab in partnership with the G-Scop laboratory wishes to integrate into the design of the elementary cell and its implementation product life cycle constraints and evaluate the impact of this new constraint on converter performance in a circular thinking.

Scientific program

The scientific challenge of this PhD project is to enable a new design way to produce mechatronic products (i.e. integrated electronics and mechanics) based on standardisable power electronics “bricks” with a high potential of re-circularity. The scientific issues are considerable. The main industries already in place in the electronic power 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 apply: 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 envisage some sustainable scenarios in current mechatronic products.

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

Methods to be explored and to apply: 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. Components 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 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 to last 36 months. Both laboratories are in the same location (1 km).

First Year: bibliography study & opportunity analysis by modular design of mechatronic products based on power electronics, in the objective to achieve sustainable production-usage scenarios.
Time repartition between research centres: G2Elab 50%, G-SCOP 50%

Second Year: evaluation and comparison of the envisaged scenarios: systemic and multi-indicators impacts analysis. Development of a real based case study demonstrator.
Time repartition between research centres: G2Elab 30%, G-SCOP 70%

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.
Time repartition between research centres: G2Elab 70%, G-SCOP 30%

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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