Beyond the quest for performance in power electronics conversion

Tugce Turkbay Romano[1,2], Li Fang[3,1], Lucas Pinto[1,3], Suzanne Guillou[1,4], Fatimata Diarassouba[1], Lucas Riondet[3,1], Maud Rio[3], Thecle Alix[2], Laura Vauche[4], Peggy Zwolinski[3], Yves Lembeye[1], Pierre Lefranc[1], Charley Lanneluc[4], Nicolas Perry[2], Jean-Christophe Crébier[1]

1- Univ. Grenoble Alpes, CNRS, Grenoble INP, G2ELAB, 38000 Grenoble, France
2- Arts et Métiers Institut de Technologie, Université de Bordeaux, CNRS, Bordeaux INP, INRAE, I2M Bordeaux, F-33400 Talence, France
3- Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, 38000 Grenoble, France
4- Université Grenoble Alpes, CEA Leti, 38000 Grenoble, France

Abstract— This paper motivates the need to look for new specifications in power electronics to account for environmental impacts. It is introduced the limits of actual quest for greater efficiencies and the opportunity to direct R&D toward sustainable and more circular design and manufacturing. The paper outlines key topics such as modularity, standardization and heterogeneity in the specific context of power electronic technologies.

Keywords— power electronics, eco-design methods, circular economy, modularity, standardization

Power electronics (PE) converters are part of the energy transition technology puzzle. Power converters are useful to interconnect most renewable energy sources and they are key to supply efficiently most of our modern needs, from the electric mobility to the supply of ICTs without forgetting air conditioning systems, consumer applications and industrial drives. In PE, the quest for performance has long been a useful "driver" and source of progress and innovation. One key achievement in power electronics is the variable speed control of motors, under very high efficiency levels and reasonable costs. Lots of efforts have been carried out to improve power densities and efficiencies, which are now close to absolute limits, leaving little room for improvement this very mature technology. On the other side, PE converters are part of this fast growing mountain of Electronic and Electric Equipment Waste. We are facing a growing dilemma between the need to use PE to support energy transition for climate change mitigation, and the risk to produce undesirable impact transfers with pressure on resources, pollutions, waste, etc…

The development of an industrial sector and a conversion technology compatible with a circular and sustainable economy is becoming critical. In our decision-making processes, definition of PE device specifications, design and production, technological choices and usage needs and conditions, it is urgent to question preferences and objectives to commit the sector to a sustainable future.

To this respect, it is now necessary to assess the environmental impacts of PE technologies, not only from the energy and CO_2 perspectives, to guarantee that it will help complete the energy transition without leading to impact transfers that would shift the problem to other planetary boundaries or environmental indicators. In that respect, carrying Life Cycle Assessment (LCA) on product systems, meaning over each life stage of the product and questioning its function is important to support sustainable decision-making, design and manufacturing choices. Developing methodologies that will impact the design process, as early as possible, is also necessary. This is not easy because databases for LCAs are not populated with references for PE fields. Additionally, it remains difficult and complex to introduce new paradigms and new design thinking in a very technological and multidisciplinary field. This is therefore an important challenge with numerous bottlenecks!

Looking at the deployment of the circular economy -or even better the functional and "cooperative" economy – in power electronics is another challenge. Indeed, just like the electronic boards of most products, PE converters are often sub-systems of a product. Consequently, the development of circularity in PE is to be considered and built taking into account the various practices of its numerous applications. Circularity in PE is therefore, above all, conditioned by the "accessibility" of the converter as such (disassembly, collection and diagnosis). Then secondly, it is conditioned by how the converter is designed with regard to one or more of the following scenarios: repair, reconditioning, direct reuse at the end of use or even recycling, as illustrated in figure 3 below. It is necessary to reconsider the design of power converters to “prepare” and/or to ease for circular options, making them easier to diagnose, to repair to refurbish and ultimately to recycle. Today, because of the diversity of materials, components, topologies, control strategies etc… the complexity and the heterogeneities of power converters, as illustrated by the pictures in figure 1, is making difficult the implementation of circular options.

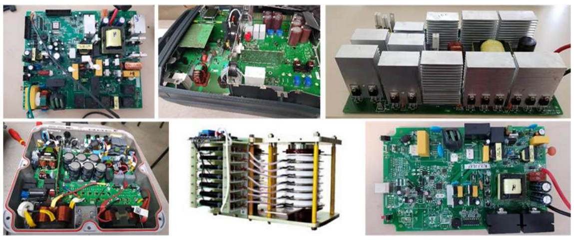

Figure 1 - Examples of power converters outlining the diversities and heterogeneities of the technology.

Preserving the PE converter’s residual functional value and delaying its end of life/end of usage, recycling and energy recovery is expected to reduce the environmental impacts of the technology although this could lead to rebound effects. It is therefore important to look at PE electronics technologies sustainability not only from the technical point of view but also from the socio-environmental point of view. In this perspective, we need to introduce non-technical factors and we need to look at different scales of the product, within the product (i.e. sub-components) but also at the industry and society levels over the time scale of the technology. For instance, some researchers propose to develop a prospective “fleet” or “cumulative” vision of the deployment of products [1], [2], as illustrated figure 2.

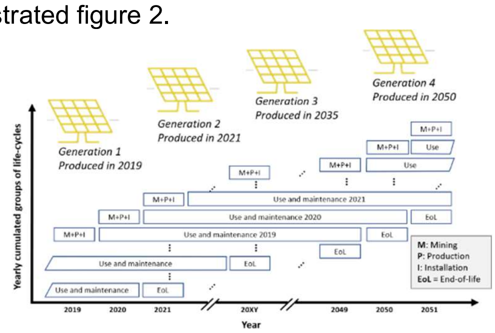

Figure 2 – Illustration of a “fleet vision” applied to the deployment of PV systems integrating their lifecycle stages, adapted from [1].

Such approaches are supported by recent developments of the *prospective LCA*, meaning to anticipate environmental impacts based on socio-technical scenarios [3], [4]. Considering prospective scenarios focused on how technologies integrate society levels will help designers to identify socio-technical levers and to clarify the consequences of industrial and design choices. At G2Elab, with our academic and industrial partners, we develop tools, metrics and associated databases to support the assessment of power electronics technologies environmental impacts [5], [6], [7]. We are also developing modular and standardized designs in power electronics, easier to diagnostic, to assemble/disassemble and repair, to promote the operationalization of the circular economy in EP and make the community more sensitive to circular options from technical but also business points of view [8], [9], [10]. We are studying the impact of heterogeneities present at multiple levels in the converter and how it is possible to change design and manufacturing options in order to reduce their negative impacts on circular options.

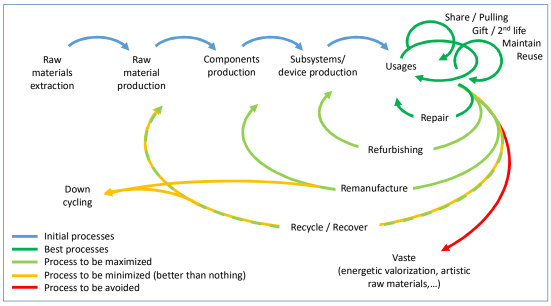

Figure 3 – Illustration of circular economy strategies within a lifecycle vision for products

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