MEDEE NEWS

Newsletter of the research cluster MEDEE - N°9 - July, 2017

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> The Hauts-de-France Region is ready to design the « 21st-century electric motor ».

EDITORIAL

MEDEE: « Maîtrise énergétique des Entraînements Électriques (Electric Drive Energy Management)» or « Motors and Electrical Devices for Energy Efficiency ». For over 10 years, the research centre's DNA has been made of projects on innovative electrical machines and transformers.

Even if MEDEE's scientific community's skills have recently been recognised in the field, working on Smart Electric Grids still requires to solve a few Electrical Engineering problems first.

The CE2I project, which we are presenting in this newsletter, is a very ambitious project supported by Lille 1 University and Professor Betty Lemaire-Semail, on behalf of the seven other supervisory authorities of the former Nord-Pas-de-Calais Region and funded within the 2015-2020 CPER framework.

CEII: an Integrated and Smart Energy Converter (Convertisseur d'Energie [CE] Intégré [I] et Intelligent [I]):

It is meant to be embedded since the technological ambition is to design monitoring, control and supply systems which will be embedded inside the machines themselves… It is an energy efficiency, compactness and high-temperature resistance challenge meant to match industry's new requirements regarding on-board systems in particular.

It is meant to be smart since the aim is to design fault-tolerant machines with a control system that will include self-reconfiguration functions. As it used to be said about our motor-cars a few years ago, "Running on three out of four cylinders is still better than being stopped in the middle of nowhere!" There again, the number of potential industrial applications concerned is huge.

Many technology locks have to be removed: high-performance insulating materials or magnetic steels to be developed, converter architectures to be invented, innovative heat-removal devices…

All those challenges are what the scientific community and all its research fields together propose to take up. This is undoubtedly where the major strength of the project lies.

The door is also wide open to industrial manufacturers, international groups or start-ups in search of new markets who would expect to benefit from CE2I to promote their innovations: MEDEE will know how to provide them with the required support to develop collaborative projects contributing towards the improvement and enrichment of what the "21st-century motor" will be like.

See you very soon and « fair currents » to CE2I!

Paul DUCASSE,
MEDEE CEO

Meeting with Betty Lemaire-Semail

Betty Lemaire-Semail has been a Professor of Electrical Engineering at Lille 1 - Sciences and Technologies - University since 1998. Being appointed at Polytech'Lille, she has been at the head of the Electrical Engineering and Power Electronics Laboratory (L2EP) since 2015 and the coordinator of the CE2I project.

The Hauts-de-France Region is ready to design the « 21st-century electric motor ».

The European Energy Transition thrust and the former support to MEDEE's industrial and academic partners, through the 2007-2013 "Contrat de Plan État Région" (State and Region plan agreement) have convinced the Nord-Pas-de-Calais Region to include the "high-currents electrical components and systems" content in its "2014-2020 Research and Innovation Strategy" – Smart Specialisation" (SRI-SI). This decision promotes the launch of new collaborative R&D projects supported by regional, national and European funds - ERDF: European Regional Development Fund - in the electrical engineering field.

The all-electric trend, the flexible use offered by electrical power, the accessible gains in energy efficiency bring about new research topics on electric machines and associated static converters (transformers, electromagnetic actuators, inverters, etc.) and are in line with research cluster MEDEE themes.

Technological jumps are to come thanks to emerging wide-bandgap semi-conductor components – SiC, silicon carbide and GaN, gallium nitride –, the new generation of organic and inorganic insulants, and the birth of novel and high-performance control architecture for polyphase machines. These developments shake up the current thermal, mechanical or dimensional constraints and lead to a foresight of the "21st-century motor", which will include new features while complying with high-standard compactness, modularity and reliability.

This is the challenge the academic and industrial partners of the CE2I – Convertisseur d'Énergie Intégré Intelligent / **Smart Embedded Energy Converter** – project have decided to tackle within the scope of the 2015-2020 CPER (State and Region plan agreement).

The CE2I project gathers the regional electrical engineering academic actors in order to face the multidisciplinary issue head on. L2EP, the Electrical Engineering and Power Electronics Laboratory (Lille 1 University, Ecole Centrale, ENSAM, Yncréa-HEI), LSEE, the Electrical Engineering and Environment Laboratory (Artois University), LAMIH, the Industrial and Human Automatic control, Mechanical and Computer Engineering Laboratory (University of Valenciennes and Hainaut-Cambrésis) and URIA, the Computer and Automatic Control Engineering Research Unit (Institut Mines-Telecom Lille-Douai), are also major academic actors of the CE2I project. Its aim is to develop a comprehensive system combining the functionally and structurally reliable electromagnetic actuator and the wide-bandgap component-based static converter. The system will have to comply with compactness, eco-efficiency and modularity conditions to match the requirements of a wide range of demanding applications. The implementation of the project requires the development of modelling as well as electromagnetic and thermal-optimization tools.

Energy efficiency, eco-design, degraded mode operation, sturdiness, reduced mass and dimensions, embedded cooling device, life-cycle analysis… are the keywords of this project.

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What are the reasons for this project ?

Betty LEMAIRE-SEMAIL
The use of electric power is spreading out more and more in the fields of manufactured productions, energy production, transports and mobility. In order to help with the design of a complex system including an electrical energy converter and thereby amplify the trend, it is fundamental to provide a range of "plug-and-play" converters ensuring all the above-mentioned qualities and being able to adapt to environments with severe conditions of use.

Nowadays, static energy converters mostly remain apart from the electrical machine. Yet, reducing the volume of fittings reveals a major stake for the aerospace, railway, automobile and wind- power industries. Yet, the compactness objective brings about the constraint implied by the closeness and integration of the two items – static converter and machine –, taking the thermal limit factor into account. The birth of fast and high-temperature components, such as silicon carbide (SiC) or gallium nitride (GaN) components, now helps tackle the issue.

The avionics, wind-power and marine-power fields are interested in the structural and functional reliability of converters. These must ensure an outstanding sturdiness and safety in case of overheating and over-current or in case of mechanical hazards. The converter-machine assembly will carry on operating in degraded mode and will ensure continuity despite faults, failures or else, and will reconfigure itself without any human intervention. The converter will have to prove to be "smart".

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What is the link with the environmental issue ?

Betty LEMAIRE-SEMAIL
The Third Industrial Revolution makes electric power indispensable because of the flexibility of its use, its modularity and, above all, its light environmental impact, given that it can be produced from fully renewable energies. Electric drives, being already widely used in the industrial sector, are at the heart of the research cluster's preoccupations MEDEE and are to expand and deploy over a maximum of applications in order to limit the use of other energies that would be more environmentally harmful.

In this context, it is fundamental to increase the supply in energy converters in order to make the choice and use of them easier in the industrial world. Promoting the clean electrical solution also contributes to a sustainable development.

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What does this project consist of and how is it organised ?

Betty LEMAIRE-SEMAIL
The CE2I project is based on seven tasks (each one dividing into sub-tasks).

This multi-task process, as represented in figure 1, requires parallel approaches.

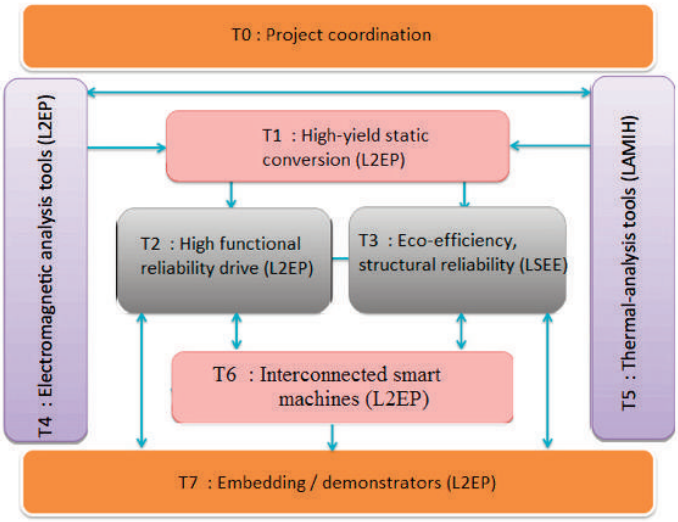
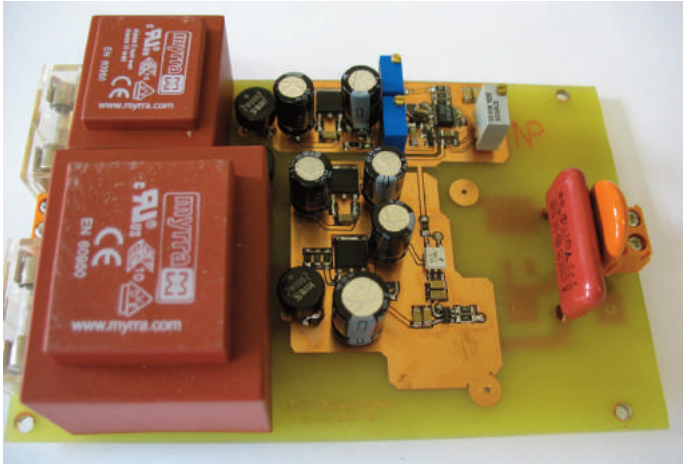


Figure 1 : CE2I-project scientific organisation

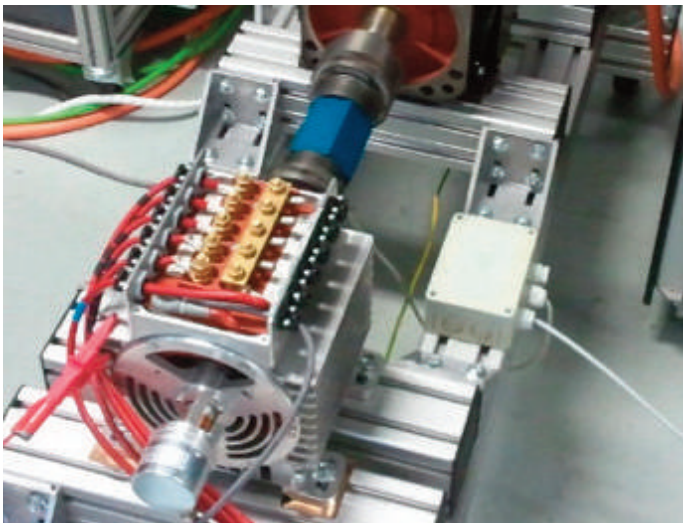
The tasks (T1, T2, T3) devoted to the development of the converter items and of the interconnection of the converters (T6) are linked with tasks T4 and T5 which are dedicated to the development of electromagnetic and thermal-analysis tools. As a final objective, the development of a 40-kW (converter) technology demonstrator is planned as task 7.

Task 1 is related to the development of a high power-density and high-yield static converter (picture 1) using wide-bandgap components and being high-temperature resistant.



Picture 1 : GaN transitor-based converter – L2EP

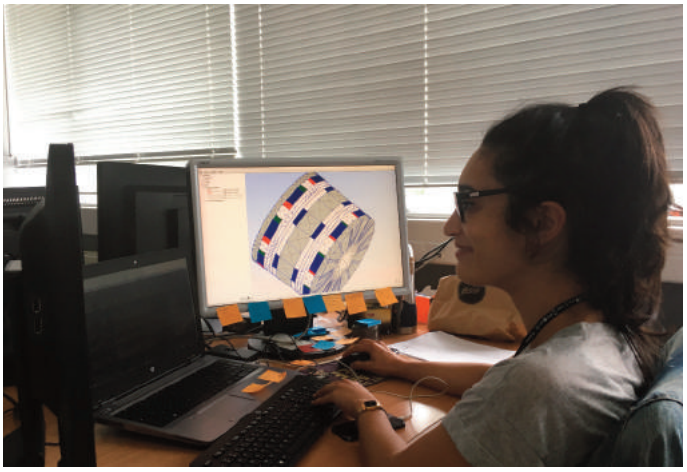
Tasks 2 and 3 (pictures 2 and 3) respectively focus on the development of fault-tolerant polyphase machines and on the development of structurally reliable low-mass and high-temperature-resistant machines.



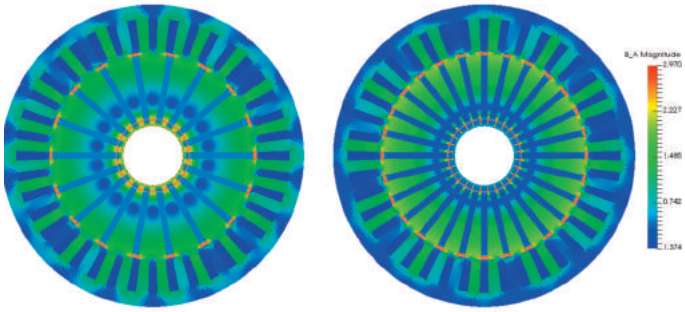
Picture 2 : Prototype of a 5-phase permanent-magnet machine – L2EP

Picture 3 : Flat anodized-insulant coils - LSEE

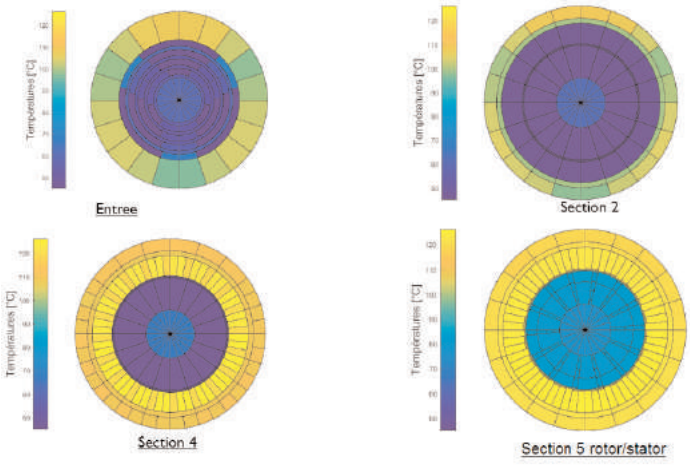
Tasks 4 and 5 are devoted to the development of numerical modelling tools in the electromagnetic and heat-transfer fields (pictures 4, 5, 6) that will be applied to the prototypes produced along the process of the project. The optimisation phase and the coupling of the two domains will also be dealt with.



Picture 4 : Machine modeling - LSEE



Picture 5 : Magnetic induction in the modelized machine under the code_Carmel calculation code[1] - L2EP



Picture 6 : Thermal mapping of the machine obtained through the SAME code (Aerothermal Simulation of Electric Machines) - LAMIH

[1] Code Avancé de Recherche en Modélisation Électromagnétique / Electromagnetic Modelling Research Advanced Code

The development of the project will stretch over the 2015-2020 period and probably slightly more. The work will involve permanent researchers and teacher-researchers from the partner university units together with researchers and engineers recruited thanks to CPER dedicated funds or by industrial partners. In addition to informal exchange meetings between the contributors to the various tasks, two scientific monitoring committee meetings will be organized each year, as well as an institutional steering committee. Those meetings will provide the opportunity to check the progress of the project according to the intermediary deliverables and the indicators as well as to schedule further actions and funding claims.

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What are the expected results ?

Betty LEMAIRE-SEMAIL

Many results are expected in the scientific and technical fields. Even though it has a definite applied purpose, the project involves many scientific challenges which can be dealt with thanks to the synergy created between the various partners. Questions still remain to be resolved, such as the integration of simultaneous cooling systems for the electronic components and the machine, the continuity of operation within a degraded and thermally stressed environment, the electromagnetic cleanliness of the converters despite the high operating frequency, the use of high-temperature insulants (etc…) will give rise to scientific diffusions or to the registering of patents.

The CE2I project will impact the economic, societal and territorial levels.

From an economic point of view, in addition to the enhanced partnership provided by businesses and MEDEE cluster's laboratories, this project will request the participation of investments from high-tech small or medium-sized businesses. The regional skill-network will help the setting-up of start-ups. The CE2I project will establish machine qualifications, accredit the action plans, hence creating new eco-efficient labelled standards.

The industrial economic repercussions of the project are expected in the budgets devoted to new-work and operating/maintenance activities. In fact, the aim of the academic and industrial actors of this project is to design a "plug-and-play" type converter. That "turn-key" tool will offer a range of power-rates matching the applications targeted. Integrating this energy converter into an industrial process which is originally without it or hard to reach (marine turbine) provides a better energy efficiency, a flexible operating mode and an intrinsic service continuity.

In order to improve the renewable part of the electric mix, the decentralized energy sources are increasing. The transformations of our energy background calls for more energy converters. Thanks to this smart and sturdy converter, the production of electric power from renewable energies will benefit from this converter family.

Gains in power-weight ratios and in consumption are expected in the automobile, railway and avionics fields. The spread of hybrid motorization or of on-board electric network new technologies will reduce the carbon cost. Renewable-energy production systems will significantly improve in their design and installation costs, as well as in energy efficiency gains. The decreasing production of fossil energy will eventually improve the quality of our environment.

Concerning the territorial development, the region will promote the participation of small and medium-size businesses and high-tech investments : hence a major benefit towards the creation of a regional skill network and to help the setting-up of start-ups in the energy-converter field.

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What are the industrial targets ?

Betty LEMAIRE-SEMAIL

Owing to its nature, this project will be a response to several issues such as the size and mass reduction issues of aerospace on-board systems, or the production of renewable energies – wind and marine turbines –, technology changes, electrical mobility – motor vehicle equipment manufacturers, hybrid vehicles, railway and maritime transports – and the reliability of industrial processes – service continuity.

MEDEE
What is the position of this project in France and worldwide ?

Betty LEMAIRE-SEMAIL
The original approach of this project is based on the simultaneous implication of several academic and industrial skills within the same consortium. The whole project relies on four of MEDEE's laboratories and seven higher-education and research institutions specialising in electrical engineering, power electronics, heat-transfer technologies, computing and automatic-control engineering. The strength of this gathering lies in the research teams' fundamental complementarity and their will to collaborate within the Nord-Pas-de-Calais region.

As the promoter of the project, L2EP – the Electrical Engineering and Power-Electronics Laboratory – studies, designs and makes the static converters, develops efficient digital and methodological models, designs fault-tolerant machines, approaches the interconnection aspect of the electrical machines, thereby validating the functional reliability of the CE2I project.

LSEE – the Electrical engineering Systems and Environment Laboratory – provides its skills for the design of eco-efficient electrical machines. It adapts the magnetic and dielectric materials to the new constraints induced by the fast components. LSEE defines the structural reliability.

URIA – the Computing and Automatic control Engineering Research Unit – is involved in the analysis of the power converter data in order to produce a real-time diagnosis.

LAMIH – the Industrial Automatic control, Mechanics and Computing Laboratory – covers the skills in heat-transfer and cooling technologies.

Several European and American projects do exist in the field, which confirms the topicality and relevance of the economic and scientific issue. As the programming the CE2I project benefits from is a longer one (5 years of R&D), it features the peculiarity to integrate the whole set of constraints – heat transfer, functional and structural reliability, eco-efficiency, EMC (Electromagnetic Compatibility Directive), interconnection – at the same time along the design process of the energy converters. Inside each task, the latest internationally-produced scientific advances will be tested in order to optimize the performances of the final device.

MEDEE
What interests does an industrialist have in participating in the project ?

Betty LEMAIRE-SEMAIL
A showcase for both the industrialists involved and the research world, but not just that…

The industrial world will find an accessible benchmark highlighting upscaled technical skills. This project will be a key-support for businesses in their response to calls for project proposals regarding the "smart embedded energy converters" theme.

As members of the research cluster MEDEE, industries will benefit from the Hauts-de-France Region's skills through this demonstrator on the consumption, reliability and electromagnetic emission matters. The future partners will discover the know-how of Northern France's scientific community.

MEDEE
What is the budget of the project ?

Betty LEMAIRE-SEMAIL
The CE2I project requires substantial material and human resources. The whole process of the project will require the participation of some fifty post-doctoral researchers, research or design engineers and twenty to thirty Ph.D. students (not included in the CE2I budget). Some thirty permanent researchers from the seven university units concerned are also involved in the project.

The overall cost of CE2I amounts to 11 million euros. The state, the Region's Research and Technology Agency together with the Hauts-de-France Region's board for Research, Higher Education and Health's share of the budget will amount to 4.6 million euros. The balance will be covered by the ERDF's European Regional Development Fund (FEDER's), the industrial partners'[2] and the supervising authorities' equities.

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What are the national and international collaborations expected ?

Betty LEMAIRE-SEMAIL

On a national scale:

- The motor vehicle and railway equipment-manufacturers' and the aerospace sector's expectations give structure to the CE2I project. This industrial focus sets the operational and intermediary applied research lines. The research cluster's industrial members MEDEE can support one or more stages of the CE2I project.
- Associations with regional laboratories – the Electronics, Microelectronics and Nanotechnology Institute, the Paul Painlevé mathematics Laboratory – provide an identified expertise to one of the project tasks. Other regional laboratories may be occasionally involved later on in order to inject specific skills.

On an international scale:

- Collaboration agreements are under way with Sherbrooke and Eindhoven universities (LN2/ Nanotechnologies and Nano systems Laboratory in Canada and a Polytechnic school in the Netherlands) and are planned with the university of Gent (UGent, Belgium) in order to include external know-hows on several parts of the project.

[2] Consistent with the research subjects in the industrial challenges, seven industrialists signed a lette of support : Jeumont Electric, Auxel, Thales Aliena, EDF, ThyssenKrupp, Valeo, Safran.

Presentation
of Electrical Engineering and Power Electronics Laboratory (L2EP)

L2EP laboratory was founded in 1989 by four partner institutions : the University of Lille 1 - Science and Technology, Arts et Métiers ParisTech - Lille Campus, Ecole Centrale de Lille and École Hautes Études d'Ingénieur (Yncréa-HEI). It groups together in Lille, within the same laboratory, all R & D activities in Electrical Engineering.

L2EP has an international presence with foreign academic collaborations (University of Toronto - Canada, Harbin Institute of Technology - China, Polytechnic School of Turin - Italy ...). It consits of four complementary teams which works revolves around the control of electrical systems, power electronics, electromagnetic modeling, optimization of electrical devices and power grids. Today, 107 people as teachers-researchers, IATOS staff, doctoral students, non permanent staff constitute the laboratory.

The L2EP, actor in the research cluster MEDEE, has a collaborative research activity with others laboratories (LSEE, LAMIH, IEMN, CRIStAL, IRCICA, LEC...), a partnership with industrialists, SME, international groups (Jeumont Electric, Safran, Alstom Transport, Engie Green, Auxel...). Moreover, EDF is associated with CE2I through the LAMEL - Electrical Equipment Modeling Laboratory - a joint laboratory with L2EP.

The L2EP brings its expertise to the national scientific network MEGEVH (Energy Modeling and Energy Management of Hybrid Vehicles), to the RT3 (Technology Research on Land Transport) of the Ministry of Reseach. The L2EP joined the Carnots ARTS Institute (Research for Technology and Society), a national organization in answer to the development of technology transfer and promotion of innovation.

The L2EP, winner of the INPI Trophy (National Institute of Industrial Property) for Innovation 2012, brings together research activities in Electrical Engineering on high voltage and power converters.

In 2014, L2EP and EDF r&D signed a research framework agreement on the thematic area of intelligent electrical systems focus on decentralized electricity production in the electric systems of tomorrow.

In January 2017, L2EP and RTE France signed a framework agreement – joint comitment on five year scientific program – to continue their investigations on the penetration of power electronics into power grids. Three European projects (Twenties, Bestpath, Migrate) and a collaboration on « Powergrid Campus Lille » project constitute the complements formalized by this contract and research associate works.

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with financial support of
EUROPEAN UNION
European Regional Development Fund
Région Hauts-de-France