# French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of 15 engineering schools/universities. The document also provides information about the supervisor. Please contact the PhD supervisor by email for further information regarding your application.

## Supervisor information

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| **Family name** | Badel |
| **First name** | Adrien |
| **Email** | Adrien.badel@univ-smb.fr |
| **Web reference** | https://scholar.google.com/citations?user=_7EBsHAAAAAJ&hl=en |
| **Lab name** | SYMME |
| **Lab web site** | https://www.univ-smb.fr/symme/ |
| **Polytech name** | Polytech Annecy Chambéry |
| **University name** | Université Savoie Mont Blanc |
| **Country** | France |

## PhD information

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| **Title** | New approaches for efficient energy harvesting from ambient magnetic fields. |
| **Main topics regards to CSC list (3 topics at maximum)** | VI. Engineering science (VI-2 Prevention of serious engineering breakdowns and system safety, VI-6 Micro electromechanical technology) |

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| **Required skills in science and engineering** | Electrical engineering; power converters; energy; electronics; electromagnetism; multiphysics. |

## Subject description (two pages maximum including biblio)

**Background**

Wireless sensor nodes designed to facilitate monitoring, risk prevention, and more generally improve comfort in our day-to-day life, are increasingly present in our everyday environment. Most of these devices require a fairly small amount of energy to sense, process, then send an information. This makes energy harvesting an attractive alternative to electrochemical batteries, as it could lead to devices combining compactness, long lifetime, and robustness to harsh environments.

In the case of smart grid monitoring, magnetic field energy harvesters constitute a promising solution to power wireless sensor nodes. Magnetic field energy harvesting consists in harnessing the energy around AC power lines, by converting the ambient magnetic field in a rectified voltage that can supply a sensor. The power line is surrounded by a toroidal magnetic core which canalizes the magnetic field lines. By wrapping a coil around this magnetic core, the varying magnetic field in the core induces a voltage across the coil (Lenz law) which can be rectified and conditioned to power a sensor. With such technology, the harvested power is limited by the magnetic saturation of the core. [A]

**Thesis**

This thesis focuses on the modeling, design and optimization of innovative solutions for efficient energy collection from ambient magnetic fields. The PhD candidate will derive a model of magnetic field energy harvesters, taking into account the saturation and nonlinearity of the magnetic core. This model could be validated with numerical finite element simulations, and on a dedicated testbench with custom magnetic field energy harvesters.

Thereafter, the PhD candidate will explore magnetic and electrical circuits techniques in order to optimize the extracted energy from the harvester, while optimizing the magnetic flux in the magnetic core. Many approaches could be explored in order to realize such optimization: clever design of the geometry of the magnetic core, optimization of flux-shaping capacitors [B], control of the magnetic flux with feedback coils, impedance matching using multiple coils series and parallel connections, development of nonlinear switching interfaces [C], etc. The PhD candidate will analyze these solutions on circuit simulation software, and fabricate promising electrical solutions on printed circuit boards in order to experimentally validate their performances, using the available LPKF machining in the lab.

Hybrid solutions combining electromagnetic [A] and electrodynamic [D] technologies could also be studied and fabricated. By properly including resonant magnets and varying tunable air gaps inside the magnetic circuit of a magnetic field energy harvester, both power density and saturation limit could be increased.

The scaling of the proposed solutions, both in terms of power line current and avalaible volume, will be studied. Such analysis will allow to propose general design guidelines for optimal magnetic energy harvesters, depending on the available energy and volume.

In the last part of the thesis, the PhD candidate will develop a self-powered self-adaptive version of the electrical interface, in order to power a wireless sensor without battery. Such autonomous implementation could be presented as a demonstration in international conferences and symposia. All developed solutions will be tested on experimental testbenches in the lab, and the results of these studies will be published in prestigious journals in the field of electromagnetics, energy harvesting, and power electronics.

## Tasks percentages

15% literature review and background
25% electromagnetic and electromechanical model of the harvester. Analysis and optimization of the model.
25% analytical and numerical studies of electrical circuits and electrical techniques in order to maximize the harvested power
20% Experimental validation on a dedicated testbench
15% Publications and manuscript writing

## General requirements

Background**:** You should have earned an MSc degree at a recognized institute for higher education. You should have a background that fits the requirements of the project: electrical engineering, electronic engineering, electrotechnical engineering, or applied physics. Students with other backgrounds who can demonstrate a strong track record with high learning ability are also welcome.

English: You should be able to communicate well in English (written and oral).
Provide TOEFL/IELTS scores if available.

Team player: You should be able to work well in a team of other project members.

## References

[A] Lin Du, Caisheng Wang, Xianzhi Li, Lijun Yang, Yan Mi, and Caixin Sun. (2010). A Novel Power Supply of Online Monitoring Systems for Power Transmission Lines. IEEE Transactions on Industrial Electronics, 57(8), 2889-2895. doi: 10.1109/tie.2009.2037104
[B] Jinyeong Moon, Steven B. Leeb. (2016). Power Electronic Circuits for Magnetic Energy Harvesters. IEEE Transactions on Power Electronics, 31(1), 270-279. doi: 10.1109/tpel.2015.2401336
[C] Emmanuelle Arroyo, Adrien Badel. (2011). Electromagnetic vibration energy harvesting device optimization by synchronous energy extraction. Sensors and Actuators A: Physical, 171(2), 266-273. doi: 10.1016/j.sna.2011.06.024
[D] Jing'ao Huang, Xiaoming Wu. (2015). A piezoelectric alternative magnetic field energy harvester with permanent magnet bias. 2015 International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale (3M-NANO). doi:10.1109/3m-nano.2015.7425459