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

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information	
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Country	France

PhD information	
Title	Unified modeling formalisms of EDO / EDP for optimial design of power systems
Main topics regards to CSC list (3 topics at maximum)	V- **Energy and environment**

	V-4 New technology of high-performance energy economics
Required skills in science and engineering	Electrical Engineering major, background in applied mathematics and physics. Finite element softwares.

Subject description (two pages maximum)

Resume :

The transport and exploitation of renewable energies implies increasingly complex electromechanical conversion chains of multi-physical nature. Now, the nature of the organs to be modeled strongly influences the form of their representation and their modeling. The objective of this thesis is therefore to address the problem of ODE / PDE coupled modeling and numerical simulation, on applications of energy conversion chains, while trying to take into account the interactions between the different physical domain (electrical, magnetic, thermal, mechanical, aging, ...). This generic approach can permit to increase global efficiency and cost of complex electrical application (Fuel Cell Electrical vehicle, Multi-sources renewable systems, advance power electronics, ….)

PhD Title: Unified modeling formalisms of EDO / EDP for optimial design of power systems

The new energy technologies make use of complex and multi-physical conversion chains. Such multi-physics systems are generally described by very wide scales of dynamics and are related to the different physical phenomena to be modeled. Likewise, the nature of the devic to be modeled strongly influences the form of its representation. Thus, while the dynamic behavior of the power converter can be represented by a set of ordinary differential equations (ODE) or algebraic equations (DAE), its thermal model can require models based on partial differential equations (PDE).). It is the same case for the modeling of inductors, transformers and electrical machines, which can in addition resort to strong inter-domain couplings (for example electromagnetic-thermal-mechanical). It turns out that these coupled ODE / PDE modeling problems are not new. A large number of studies exist and aim essentially at looking for coupling formulations able to facilitate the work of the numerical solver [1,2,3]. In [4], an important work of analysis and formulation of PDE problems is proposed, with a view to coupling components described by simple EDOs (passive components for example) with more complex semiconductor components, modeled from EDP. In [1] and [2], coupled modeling is applied to the temporal simulation of organic cells and blood circulation. For each of these works, the methods implemented are strongly related to the nature of the addressed problems. In this sense, there does not seem to be any work specifically dealing with the ODE / PDE coupling methods applied to electromechanical energy conversion chains and their singularities. Moreover, if the coupling between a power converter and an electromagnetic system can find operational responses in the studies mentioned above, the fact remains that the problem of numerical simulation of these systems, with very great disparities in the time scales, still require an important work that we propose to address in this thesis project. Thus, we will tackle the problem of the modeling and the simulation of electromechanical conversion chains by trying, as we have already done in the past [5], to limit reformulation efforts by dedicating ourselves solely to describing without a priori the different physical phenomena and their couplings. We will then try to propose simulation methods adapted to these multi-physical and multi-domain problems. Finally, we will validate the tools developed on typical cases of conversion chains, taking into account simultaneously electrical, magnetic, mechanical and thermal phenomena, and even trying to take into account the EMC of the converter, or the aging of the most weak devices. This transversal project will rely on the complementary skills of the two teams of the IREENA laboratory, in particular by trying to couple the "system" vision specific to the activities of the team “Management of the Electrical Energy” team, with the more "physical" vision of the team “Modeling of Electromagnetic systems”.

Bibliography

[1] Quarteroni, A., & Veneziani, A. (2003). Analysis of a geometrical multiscale model based on the coupling of ODE and PDE for blood flow simulations. Multiscale Modeling & Simulation, 1(2), 173-195.
[2] Gerecht, D. (2015). Adaptive Finite Element Simulation of Coupled PDE/ODE Systems Modeling Intercellular Signaling (Doctoral dissertation).
[3] Tang, S., & Xie, C. (2011). Stabilization for a coupled PDE–ODE control system. Journal of the Franklin Institute, 348(8), 2142-2155.
[4] Tischendorf, C. (2003). Coupled systems of differential algebraic and partial differential equations in circuit and device simulation. Modeling and numerical analysis.
[5] Hmam, S., Olivier, J.C., Bourguet, S., Loron, L (2017). Efficient multirate simulation techniques for multi-physics systems with different time scales: application on an all-electric ferry design. IET Electrical Systems in Transportation 7 (1), 23-31.