POSTDOC SUBJECT

Context

The deployment of electric vehicles involves designing traction systems with the best energy efficiency in order to minimise the size of the battery. Efficiency gains are sought in each of the system components (converters, inverters, filters, motors, etc.). However, increasing the DC bus voltage to accelerate battery charging complicates optimisation of the entire system. Indeed, at the inverter output, the voltage signals are made up of pulse trains containing dV/dt ramps, voltage peaks and harmonic content, which exert electrical stresses likely to degrade motor performance or even components.

Multilevel inverter topologies are interesting because they can significantly improve the shape of power signals [1, 2]. However, multilevel converters are more expensive because they contain more components. In this context, it is crucial to be able to demonstrate what the best compromises are, in terms of cost and performance.

Challenge

The aim of the post-doctorate is to develop a numerical simulation of motor/inverter systems, with a particular focus on the performance of materials under the effect of electrical stresses from the inverter.

Conventional modelling of the inverter/motor coupling is carried out using an equivalent electrical circuit. This approach proves to be too approximate for dimensioning materials [3]. The electromagnetic response of the motor must be described with consideration of its 2D or 3D geometry and realistic material constitutive laws. However, Finite Element (FE) analyses, which are suitable for these problems, are very time-consuming to compute, which means that they are unable to handle the different physical scales and characteristic times.

In a break with the current state of the art, the post-doctoral student will be able to optimise engine components on the basis of a reference case, taking into account the nature of the materials and their geometries as input parameters.

The three CEA teams involved are LITEN/LMCM [4,5], LETI/LAIC [6-8] and LETI/L2EP [9], which will be able to provide complementary support for the post-doctoral student's work.

The objectives of the post-doctorate are:

1) To develop a robust numerical simulation of systems coupling inverters and motors in a Matlab/Simulink (or equivalent) environment capable of taking into account, for

each of the blocks, the different physical scales and relevant characteristic times as well as feedback and control. This Matlab instance will have to be interfaced, on the one hand, with a 'circuit' type solver describing upstream the topology of the inverter and supplying the power signals and, on the other hand, with an electromagnetic solver by FE (Flux/Altair or equivalent) or associated reduced models describing the response of the motor at the material scale.

2) To formulate physical models capable of predicting the response of new materials under the effect of 'electrical stresses' from the inverter. In order to account for their behaviour on the scale of the motor, homogenisation techniques will be used to define the response of an equivalent medium.

3) To use simulation to establish the performance gains achievable on use cases with the inverter topologies and materials being developed at CEA.

4) To implement in this software environment a function for optimising motor components by considering the structure of the materials and their geometries as adjustment parameters.

5) To specify the test benches to be used to validate the simulation results.

References

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[4] Croset, G. et al., https://doi.org/10.1016/j.jmmm.2023.171703

[5] Pietri, T. et al., https://doi.org/10.1021/acsanm.1c00365

[6] Delattre, G. et al., https://doi.org/10.1177/1045389X221135017

[7] Boisseau, S. et al., https://doi.org/10.1088/1361-665X/abd7e8

[8] Freychet, O. et al., https://doi.org/10.1088/2631-8695/abcb4a

[9] Hemsen, J. et al., https://doi.org/10.3390/wevj10040089

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Application on the CEA website: https://www.emploi.cea.fr/