Modelling and control of a 7-phase starter-alternator for an automotive micro-hybrid application

This work deals with the study of a multiphase starter-alternator system, used for a micro-hybrid vehicle. This system is composed of a 7-phase claw-pole synchronous machine, with permanent magnets between the claws and fractional windings. It is supplied with a 7-leg Voltage Source Inverter (VSI).
In the first chapter, states of the art are given, firstly, about hybrid technologies in Automotive, then, about multiphase machines modeling methodologies, aiming at their control. A specific modeling, using the generalized Concordia transformation is pointed-out. Then, the concept of fictive machines is introduced. It has been developed at the L2EP laboratory, specifically to help the multiphase drive study. The Graphical description tool EMR (Energetic Macroscopic Representation), also developed at the L2EP, brings helps to represent the models, and offers a systematic way for the control structure design.
The second chapter deals with the extension of the models studied in the first chapter, initially developed for multiphase machines with non-fractional windings, smooth poles, and lack of magnetic saturation. This extension concerns the studied machine, showing fractional windings, salient poles and magnetic saturation effects. Besides, a generic study, based on a harmonic analysis of the multiphase machines, allows highlighting the interactions between the structure and the control of the machine. At last, an original identification methodology is developed. It is specifically fitted to the low voltage multiphase drives characterization.
In the third chapter, two types of control schemes are compared: firstly in a square wave mode. Secondly, in a Pulse Width Modulation (PWM) mode, using controls of the currents associated with the fictive machines. Experimental measurements, associated with numerical simulations, allow testing the developed models and the control methodologies. The benefits and the limits of both controls are pointed-out: The PWM control allows a better torque quality control, while the square wave control is cheaper to be implemented.
As a conclusion, the studied starter-alternator system offers simple hybrid functions, limiting the extra-cost due to the hybridization. The multiphase architecture allows increasing the system power. However, it is then necessary to reexamine the classical design and control methodologies developed for 3-phase drives. This dissertation brings methodologies to facilitate these two steps for launching this kind of multiphase drive used in Automotive.

mots-clés en anglais : **Multiphase – Claw-pole – Hybrid – Starter-generator – Fractional slot winding – Concentrated winding – Low voltage – Automotive – Control – Modelling**