High Performance Control Techniques for Multiphase eDrives

Summary

The recent energy-policies are leading to a relevant reduction in the use of fossil fuels for both energy production and transports sectors. As a consequence, an impressive electrification process involving many production sectors has recently been started. Nevertheless, this important technology step is requiring robust and reliable solutions able to replace the existing ones. Nowadays, thanks to recent advancements of the power electronics, many electrical solutions able to help towards a more sustainable future have been developed. The dissertation research activity is focused on one of these. In detail, the analysis and control of multiphase electrical machines.

Currently, the multiphase solutions are largely employed in high-power and/or safety-critical applications such as the shipboard applications. Indeed, the distribution of the electric power on more phases allows at keeping the current and/or the voltage levels to acceptable limits that can be handled with the commercial fast power electronics components. Concerning the system reliability, this is significantly improved as the higher number of phases leads to the redundancy from both power converter and electrical machine points of view. For these reasons, in the current scenario where the transports electrification is playing a leading role, the multiphase solutions are gaining a growing attention by the industrial producers. Nevertheless, there is a strong interest in the development of modular multiphase configurations able to use the well-consolidated three-phase technologies, thus reducing costs and design times. This kind of systems are usually called as "multiple three-phase machines/drives" and they represents the research context of this dissertation.

The multiple three-phase drive topologies allows at implementing the concept of modularity in terms of electrical machine winding and power converter structure. Indeed, the machine's stator consists of multiple three-phase winding sets with isolated neutral points. An independent three-phase power converter unit supplies each three-phase set.

In this way, the drive is configured as multiple three-phase units operating in parallel. Despite the large spreads of these multiphase drive topologies, few control solutions able to deal with a direct control of the main variables (current, flux, torque) belonging to each three-phase winding set have been developed, to exploit all the degrees of freedom offered by the multiple three-phase drives. For this reason, the main goal of this dissertation is to extend the modularity of the multiple three-phase structures also in terms of drive control scheme, thus without limiting itself to the machine configuration and power converter structure.

In detail, this dissertation deals with the design and implementation of a Direct Flux Vector Control (DFVC) scheme for multiple three-phase Induction Motor (IM) drives. The proposed control solution performs a direct and independent regulation of both stator flux amplitude and torque contribution belonging to each three-phase winding set, thus defining an equivalent modular Direct Torque Control (DTC) scheme for this kind of machines. The control scheme is designed to be fully compatible with the multiple three-phase drive topologies, using modular Voltage Supply Inverter (VSI) structures together with independent Pulse Width Modulation (PWM) voltage control of each three-phase power converter unit.

The performance of the control has been validated by means of experimental tests carried out with a multi-modular power converter feeding a quadruple three-phase induction machine prototype. The experimental results demonstrate the effectiveness and feasibility of the proposed control scheme, in terms of full drive controllability in all operating condition. Additional studies on the design and implementation of modular control schemes for multiple three-phase synchronous motor drives are on-going.