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RESEARCH TOPICS

- Modular Converters for Automotive
- Electric Motor Design for Automotive Traction Applications
- Multi-level Powertrain and Vehicle Dynamics: Modeling and Simulation

MODULAR CONVERTERS FOR AUTOMOTIVE

Keywords: Power converters, Modular converters, Parallel converters, Automotive, Electric vehicles, Redundancy, Reconfigurability, Scalability, Synchronization.

In the field of static power converters, interleaved converters are widely adopted in the megawatt range. Interleaving allows many advantages, from increased number of voltage levels to modular design of large-rating systems. The main drawback is the need of inductors that limit the current circulating among the units. Moreover, interleaved converters cannot be justified in electric vehicles, since the required power rating can be reached with monolithic designs. Other solutions, based on transformers, are used effectively in large-power systems, but their applicability in automotive is limited for size, weight and cost reasons. To improve density metrics, it is possible to shrink passive components by using wide band-gap devices, that allow to increase switching frequencies. This could enable the adoption of interleaved architectures even where they are not yet advantageous. Another possibility to scale the rated power is the direct parallel connection of converters, without interleaving. Converter paralleling without ballast components is not widely adopted, but paralleling is nowadays very common at device level, being used in power modules. Replicating this arrangement at converter level calls for high-speed synchronization techniques, that can be borrowed from the telecommunications and grid-connected power converter fields. Moreover, advanced techniques such as Active Thermal Control (ATC) can be used to address reliability and temperature-related performance issues. The desired power rating of the system is achieved by combined parallel and interleaved connection of multiple units, thus improving design effectiveness. This modular architecture at converter levels opens up many possibilities, such as the use of discrete power switches instead of modules, and allows to tackle the challenges of the automotive market: safety, reliability and cost effectiveness.

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ELECTRIC MOTOR DESIGN FOR AUTOMOTIVE TRACTION APPLICATIONS

Keywords: vehicle electrification; IPM motors; synchronous motor; permanent magnet; EV; torque density; constant-power speed range

The electric automotive powertrain development is an extremely demanding task as many related constraints shall be met simultaneously. Typically, the electrical machines for industrial applications are subject to requirements with different priorities and the designer can focus the efforts to address the main constraints first, while relaxing other specifications. On the contrary, electric motors for Hybrid and Battery Electric Vehicles (BHEV) need to combine:

- high nominal torque and power ratings,
- large overload range and performances,
- high specific torque and power density,
- wide Constant-Power Speed Range (CPSR) and relatively high maximum speed,
- high reliability,
- good energy conversion efficiency,
- affordable cost.

Today automotive industry and research agree considering synchronous IPM (Interior Permanent Magnet) motors to be one of the best solutions for these challenging requirements. By means of the MTPA (Maximum Torque per Ampere) control and the flux-weakening technique, IPM machines provide excellent torque and power performances even beyond 10'000 rpm.

In such a complex context, however, the design process involves inherently a multiple-object optimization problem, in order to find the most suitable trade-off among the possible choices for the machine parameters. Therefore, more and more accurate design-oriented models shall be developed along with novel motor structures.

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MULTI-LEVEL POWERTRAIN AND VEHICLE DYNAMICS: MODELING AND SIMULATION

Keywords: vehicle dynamics, vehicle modelling, powertrain modelling, vehicle electrification, control algorithms

Growing interest towards the electric mobility brings new challenges in the automotive area. Absolutely, important research efforts are focused on the development of vehicle simulators, which can be used as testbenches for the design of the single subsystems of an electric vehicle as well as essential tools oriented to produce a proper description of the vehicle system as a whole. More precisely, by making use of these simulators, it is possible to lead virtual tests for the powertrain components, that is electric motors, inverters, battery packs, etc. Moreover, the development of novel control algorithms oriented to split the torque to the wheels relies predominantly on vehicle simulation.

Naturally, there are many kinds of models: some of them are more biased towards accuracy at the cost of a non-negligible computational burden, others leverage on speed and lightness. For instance, multibody simulation can be exploited to obtain a deep description of the behavior of a system, whereas analytical and lumped parameters models are useful to get a global representation of phenomena connected to the vehicle dynamics. In addition, these simulators are very helpful since, provided they are fast enough, they can be embedded in control algorithms oriented to improve vehicle stability, traction, efficiency and safety.

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SENSORLESS CONTROL OF PERMANENT MAGNET ASSISTED SYNREL MOTORS

Keywords: Permanent magnet assisted synchronous reluctance machines, PMaSynRel drives, sensorless control techniques, magnetic flux observers.

In collaboration with the Universtity of Nottingham a permanent magnet assisted synchronous reluctance machine was designed and optimized aiming at improving its sensorless performance, besides minimizing the torque ripple and maximizing the power factor. Different sensorless solutions for the estimation of the magnetic flux linkage and for tracking the rotor angle are investigated and their performance compared in computer simulations. A novel strategy was proposed achieving encouraging results. More details are given in [1].

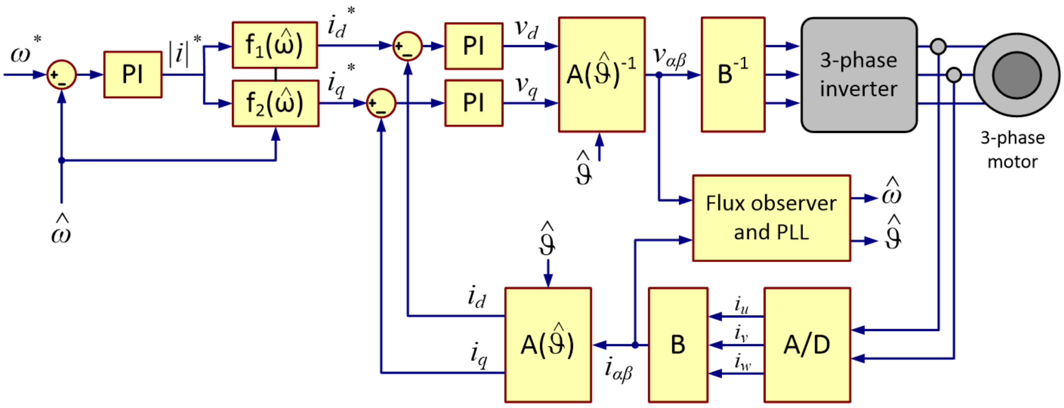

Fig. 1 - Permanent magnet assisted synchronous reluctance machine control scheme.

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