# Design optimization applied to electromechanical device prototypes

**Alberto Tessarolo**

*Engineering and Architecture Department, University of Trieste, Italy*
*E-mail: atessarolo@units.it*

**Abstract.** In recent years, new challenges have been emerging in the field of electric machine design: on one side a strong trend is developing to increase the performance of traditional machines (induction motors, synchronous generators) especially in terms of reduced power consumption, low production cost, high performance and high power density to make this equipment competitive on the market and compliant with the most and most demanding international efficiency standards. On the other side, new kinds of electric machines (especially equipped with permanent magnets) need to be developed to meet the needs of new emerging applications, particularly in the field of renewable energy generation and in the vehicle propulsion sector.

Classical approaches to the design of electromechanical equipment often show their undebatable inadequacy as means to face these new challenges. Effective answers can be instead obtained from the employment of state-of-the-art optimization design tools based on genetic algorithms. These make it possible to define a first attempt configuration of the machine, identify the design variables which can be adjusted, the constraints to be satisfied and, above all, the objective functions to be minimized or maximized. Optimization design tools automatically explore a large variety of possible design solutions in the attempt to search for the "fittest" ones based on the constraints and optimality criteria defined by the user. The adoption of smart genetic algorithm allows for the search process to run faster and converge to a solution (or to a set of solutions) supposed to be best, with final results that could never or hardly be achieved even by the most experienced designer through traditional heuristic methodologies.

A very interesting feature of design optimization tools is their intrinsic multi-objective and multi-disciplinary nature. Designs are in fact explored from a variety of viewpoints by launching electromagnetic, thermal, fluid-dynamics and mechanical analyses so as to evaluate their "goodness" with respect to multiple, possibly conflicting criteria (cost, efficiency, size, power density, etc.).

After a short overview of the most advanced design optimization environments, the focus will be placed on some recent practical applications regarding both the development of innovative electric machine prototypes and to the optimization of existing types.

Examples of innovative electric machines design optimizations which will be addressed are: a 10.000-rpm 750-kW permanent-magnet motor with magnetically suspended rotor with a target efficiency over 98%; a micro-wind permanent magnet generator with zero cogging torque suitable for operation with very low wind speeds; a permanent-magnet-assisted synchronous reluctance motor for household appliances developed as a high-performance high-efficiency but cost-competitive alternative to traditional induction motors; a high-thrust permanent-magnet synchronous linear motor capable of over 10 tons linear force developed as a full-electric drive of various shipboard equipment. For all these study cases, the design process from requirement to prototype testing will be outlined.

Finally, an industrial research and development project will be illustrated through which genetic-algorithm-based design optimization has been applied to maximize the power and performance of conventional medium-voltage induction motors, finally resulting in an experimentally proven 17% increase of motor power density.