Introduction

The world of electric machines, which is in a constant state of evolution, is seeing its field of application growing every day.

The electric machine, historically connected to a network which supplies it with a constant voltage, is today almost as a matter of course fed by a static terminal converter whose voltage varies at a rapid rate, even when its average value is constant or slowly variable.

If it appears obvious to consider the machine as one element in an electromechanical conversion chain, most of the time with a control system, the fact remains that for each new class of application, the electric machine must be examined as such.

This examination is imposed by the function itself, by the movement to be achieved, the requisite security for each element of the electromechanical conversion chain, the limitation in size, the reduction in weight, the high speed and/or the high acceleration to be reached.

In order to respond to increasingly demanding specifications, machine construction has evolved, first of all, thanks to progress made in the development of constituent materials: magnetic materials (ferromagnetic powders, permanent magnets and massive superconductors) and insulating or conductive materials (superconducting wire).

The tools of calculation, software and material, make up another aspect among those which have allowed progress in the design of machines; we are considering here the tools used to calculate fields (magnetic, electrical, thermal, force and stress fields), 3D modeling tools and optimization tools.

If the representation models progress continually in order to take into account more accurately geometric shapes (including teeth harmonics, mechanical failure), nonlinearity due to magnetic (saturation and hysteresis) or electrical behaviors (law E(J) for superconductors), nothing can replace the experience drawn from the achievements.

Nevertheless, the development of tools and the refinement of modeling allow us to perform numerous simulations leading to substantial economies in the design of prototypes and finished products.

This book aims to tackle a subject where even the definition is difficult to determine. What is a non-conventional machine?

The principles of functioning rely completely on the interaction between a magnetic field and a current (as in the majority of electric machines) or on field-to-field interaction (as in magnetic transmitters).

The movement of another category of electromagnetic motor is due to the distortion of the materials themselves (piezoelectric, shape, memory and magnetostrictive material).

This second category, made more popular, particularly by piezoelectric motors, constitutes a specific family in the area of electromagnetic converters and will not be tackled in this publication.

In the category of electromagnetic machines, non-conventional electromagnetic machines can be defined in several ways, and this is in no way the least of our difficulties.

We can attempt to provide a definition starting from the following points:

– the type of movement produced by the machine itself (rotation, linear movement, alternating movement, etc.);

– the number of degrees of freedom required (rotation or movement on one axis, combination of the two, multi-axis movement, spherical movement, etc.);

– required speeds (high, low);

– the number of coils installed and the distribution of the magnetic field;

– the geometry of the magnetic circuit (structure of the whole machine: cylindrical, flat, hollow, conical, salient or smooth structure, position of the magnets, structure of the teeth-slots);

– the materials utilized (permanent magnets, superconductors, non-ferromagnetic materials, etc.);

– the dynamic characteristics (electrical and mechanical response times, dynamic impedance, etc.);

– the forms of voltage or current delivered by its power source (voltage form and amplitude, quality of the current, etc.).

For any given application, the points outlined above can be combined to give rise to a specific and original machine.

The selection of subjects examined in this book is such that each chapter, dealing with one class of machines, is self-sufficient. The authors have written each chapter to be able to be independent for ease of reading.

An introduction to electrotechnical materials used in electrical machines, a reminder of some fundamental principles and calculation methods make up a first introduction to broach the analysis of the machines studied in Chapters 2 to 4.

This book deals with the following types of machines:

– low-speed machines, which allow us to power a charge, by removing or simplifying the mechanical gear which degrades the efficiency of the whole system. This type of machine is in direct competition with hydraulic systems, which are far better but which require robust and heavyweight channels for the flow of liquid under pressure and which need more maintenance;

– high speed machines for direct drive. The speeds of such systems generally exceed 10,000 revolutions per minute. These types of machines have the opportunity to conquer an important area, namely for high-speed machining, for electrical compression or generation and in systems where compactness and weight play an important part;

– machines with superconducting field excitation providing a high magnetic field so that an iron-free armature can be used. The second characteristic of a superconductor being to internally develop induced currents and sometimes act as either a magnetic screen or as a permanent magnet, these behaviors can be put to good use in the design of original machines.

As not a day goes by without some electromagnetic converter being developed in order to meet a specific requirement or a curiosity of research, this book is only an opened window on some electrical machines which continue to conquer market shares.