GREEN: Group of Research in Electrical Engineering of Nancy

A research center of Université de Lorraine - France

***Abstract* — This article discusses the research activities of GREEN research center and gives some technical aspects of some specific realization. The general approach adopted in GREEN lab is first described.**

I. Introduction

The GREEN-Lab was funded in the 80's and dealt with electromagnetics, electrical machines during its first decade of existence. It is a group of about 20 academic staff: Professors and Ass. Professors teaching in different campuses of Université de Lorraine. The most important ones are ENSEM (National School of Engineers in Electricity and Mechanics) and FST: Faculty of Science and Technology, both located in Vandoeuvre lès Nancy. The 90's knew the beginning of power electronics and drive, and also the use of superconductivity in electrical engineering. These two topics have grown during these last years and reached a high level of knowledge and recognition in the international scientific communities. Nowadays, Superconducting materials in electrical engineering is one of the important topics of GREEN, in addition to Electrical machines and drives.

II. Electrmagnetic modelling

Electromagnetic modelling is in the heart of research activities of the GREEN team. Both analytical and numerical home models are developed to consider many critical phenomena such as strong nonlinearities of material properties, movement, and coupled physical phenomena. Most of the time, one of the main goals is the fastness of the models, which allows their use in optimization processes with a high number of functions evaluations. As an example, Fig. 1 shows the principle of coupling 3D finite element model in nonlinear magnetostatics with reluctance network applied for the modelling and optimization of claw-pole synchronous machine. It reduces the computation time with a ratio of about 30 in comparison with full 3D FE model [1].

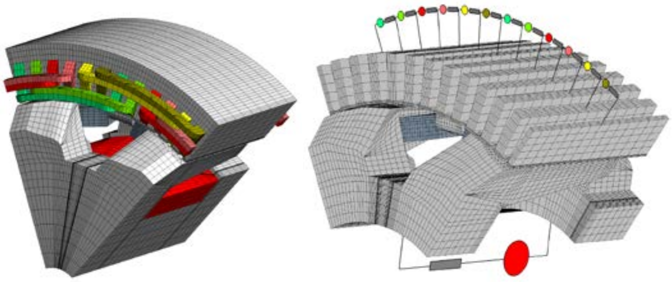


Fig. 1. Principle of Hybrid 3D-FEM – Reluctance network model applied to Claw-pole synchronous machine

II. Superconductivity in electrical engineering

It is a real challenge that members of GREEN Lab are working on. The first important point is the characterization of physical properties of different types of superconducting materials (wires, tapes, bulks …) under different conditions [2]. The research studies are led on different materials (YBaCuO, BiSrCacuO, MgB2, …) with different levels of cryogenic temperatures: Low Temperatures (4.2 K) or High temperatures (77 K) using liquid Helium or liquid Nitrogen. The magnetic and electrical behaviour of these materials have been studied for many years. The strong nonlinearity of electric field vs. current density E(J) law and its dependencies to temperature and applied magnetic field, is deeply studied. Both analytical and finite element modelling are carried out to properly characterize these materials, which will be used in electrical engineering applications such as motors, current limiters, magnetic imaging systems or SMES (Superconducting Magnetic Energy Storage).

A. Superconducting Motors

The second challenge of the GREEN team concerns the use of superconductors to develop new topologies of electrical machines so as to increase the power density for high power applications. One of the most important ideas is to use the diamagnetism of superconductors (Meissner effect) to create a kind of reluctance machines with rotors having two zones (air $\mu_r = 1$ and superconductors $\mu_r = 0$) [2]. One of the last prototypes designed and constructed is a 40kW axial flux machine with an original design of cryostat integrated in the system, so that the cryogenic performances are highly increased, Fig. 2.

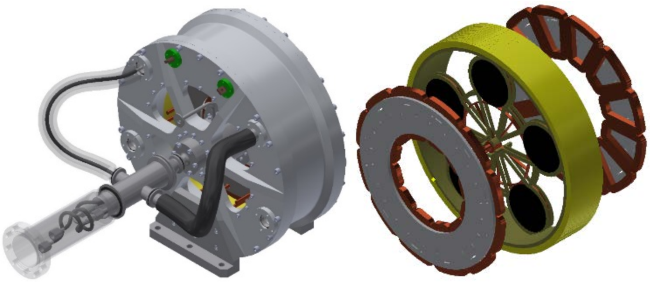


Fig. 2. Superconducting Axial-Flux Motor and its integrated cryostat

B. Bulks and Cryomagnets

There is a new application for superconductors, with a constantly growing importance, namely bulk superconducting magnets, also known as "cryomagnets". The use of massive superconducting magnets opens up the market segment of compact sources of strong magnetic fields (>2 T) at a lower price than conventional superconducting magnets. These bulks can be used in many applications that need constant magnetic field such as Motors or magnetic resonance systems (MRI, NMR). One of the applications that the GREEN team is involved in is to design and study innovative NMR systems using bulk superconductors. The physical property exploited is the ability of the superconductor to trap a large magnetic field through the creation of induced currents within the material [4]. It has been shown in laboratory that a bulk superconductor can generate up to 17T at 29K in a 2cm diameter pellet (world record to date). Hereafter, a sample of a small prototype for motor application realized and tested using in-situ magnetization, Fig. 3. It has reached a flux density amplitude greater than 2.5 T. Its thermal behavior in the cryogenic media has been optimized using numerical tools.

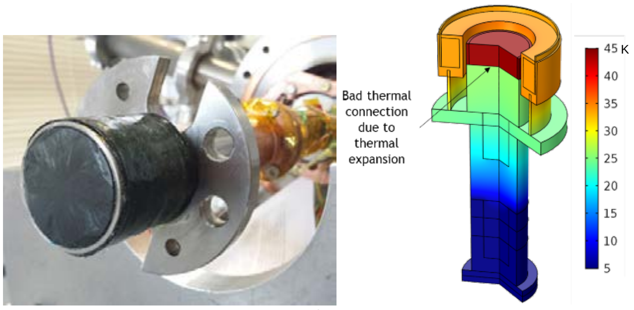


Fig. 3. Cryomagnet with its self-magnetizer – Thermal behavior

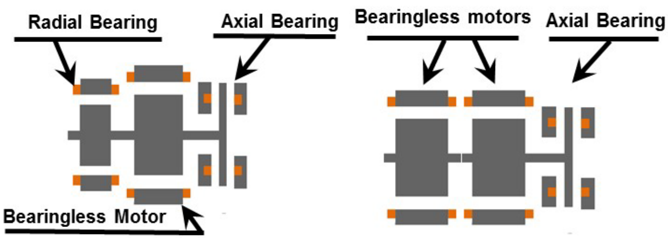
II. ELECTRICAL MACHINES AND DRIVES

The GREEN team has long experience in the design of electrical machines especially nonconventional machines as Linear motors, Vernier machines, High Temperature Motors or Hybrid stepper motors.

A. High Speed Bearingless Motors

These last years, the principle of Bearingless motors was developed and studied by many international teams such as Tokyo Institute of technology, Aalto University or Linz Institute of Mechatronics …

The GREEN team has developed interesting multi-harmonic model for the design of such machines. The consideration of the influence of each couple of harmonics to the force is one of the main contribution to this topic [5]. Researches are carried out on permanent magnet Bearingless motors with a special stator winding design. This machine provides magnetic levitation as well as torque in order to reach high speeds (up to 90krpm) and magnetic levitation with the same magnetic device. The topology 1 (Fig. 4) has been studied and tested with its special drive. The topology 2 will be developed shortly.



Topology 1 Topology 2

Fig. 4. Two topologies of bearingless motors

B. Low speed-High Torque Machines

The concept called magnetically geared induction machine (MaGIM) was introduced a few years ago. It has been studied jointly by researchers of GREEN Lab, University of Sheffield or University of Nottingham. It associates an induction machine with a magnetic gear to achieve a high-torque/low-speed drive system with extended torque transmission capabilities. The aim of GREEN Lab researchers is to improve the reliability and the performances of the traditional system associating an induction machine (IM) with a mechanical gearbox which presents mechanical problems and requires lubrication and maintenance. Topologies involving a wound rotor induction motor drive integrating a magnetic gear are studied in terms of electromagnetic, thermal and mechanical behavior. Recently a 45rpm with a gear ratio of 15.5 is prototyped in GREEN Lab, Fig. 5.

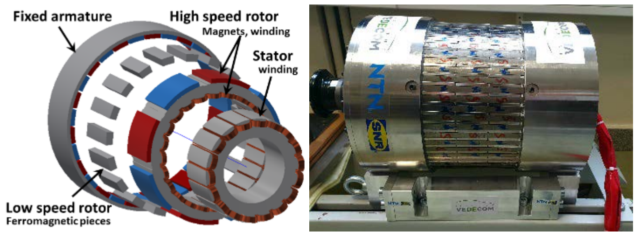


Fig. 5. Magnetically Geared Induction machine: principle and prototype

II. INTERNATIONAL SCIENTIFIC ACTIVITIES

The GREEN team is involved in many international research activities such as international scientific communities (COMPUMAG, CEFC, Applied Superconductivity, ITEC, ICEM …). Recently, the 19th International Symposium on Electromagnetic Fields in Mechatronics, Electrical and Electronic Engineering ISEF2019 (www.isef.eu) was organized in Nancy.

In 2020, the 7th Workshop on Numerical Modelling of High Temperature Superconductors will be organized by GREEN Team on May 26th -29th, 2020 (http://hts2020.eu)format of the headings and the main text is written in

VI. REFERENCES

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