PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Gianni Caiafa

XXXI Cycle

Training and Research Activities Report – First Year

Tutors: Prof. Pasquale Arpaia – Prof. Stephan Russenschuck

1. Information

PhD Candidate: Caiafa Gianni

MSc title: Master's degree in Electrical Engineering (cum laude), University of Naples Federico II

Doctoral Cycle: XXXI – ITEE- University of Naples Federico II

Fellowship type: Special Doctoral Program at CERN of Genève

Tutors: University tutor - Prof. Pasquale Arpaia

CERN tutor - Prof. Stephan Russenschuck

2. Study and Training activities

a. Courses

- Ad hoc Module, "*Field Computation and Magnetic Measurements for Accelerator Magnets*", Dr. Ing. habil. Stephan Russenschuck, November, (4 CFU)
- MS course, "*Misure per l'Automazione e Produzione Industriale*", July, (9 CFU)

b. Seminars

- "*The Magnetic Model of the LHC at 6.5 TeV*", organized by Ezio Todesco, CERN, March 17th 2016, (0.5 CFU)
- "*Magnetic system and magnetic measurements in EFFL's TCV tokamak*", organized by L.P. Hogge, CERN, May 19th 2016, (0.5 CFU)
- "*PACMAN Project: a Study on New Solutions for the High-accuracy Alignment of Accelerator Components*", organized by Manfred Wendt and Michele Modena, CERN, May 20th 2016, (0.5 CFU)
- "*The translating fluxmeter prototype: early results, Research and development on stretched –wire systems for magnetic measurements*", organized by E. Dragoni and S. Russenschuck, CERN, May 27th 2016, (2 CFU)
- "*Stray Field Measurements*" , organized by Andrea Latina, CERN, June 28th 2016, (0.5 CFU)
- "*Italo Gorini 2016*", Doctoral Summer School promoted by the Italian "*Electrical and Electronic Measurement*" (GMEE), Cagliari, September 5th – 9th 2016, (3.7 CFU)
- "Scientific writing", organized by CERN, October 13th-14th 2016, (2 CFU)

- "*3D computation of magnetic fields and induced currents in hysteretic media with time-periodic sources*", organized by Guglielmo Rubinacci, CERN, October 21st 2016, (0.5 CFU)

c. External courses

- External Module, "*French language course – A1*", May, (7.5 CFU)
- External Module, "*Electrical Approval Certificate*", June, (2.5 CFU)

3. Research activities

Title: A Magnetic Measurement System to extract Pseudo-Multipoles in Accelerator Magnets

For accelerator magnets such as capture solenoids, fragment separator dipoles, and insertion quadrupoles, it is important to measure not only the integrated field errors, but also the local field distributions in the magnet extremities. In 3D field problems, the transversal multipole coefficients do not constitute a complete orthogonal function set. This gives rise to pseudo-multipoles in Fourier-Bessel series that can also account for field variations in axial direction.

In order to develop a tool for series measurements of the magnets of the CERN project High Luminosity-LHC, a complete measurement system will be prototyped, through design, construction and metrological characterization during the PhD research activity.

The system will be composed of high-precision mechanics with integrated real-time automatic control and drive system, encoders, and measurement transducers with iso-perimetric search coils. A suitable post-processing tool must be developed based on the theory of pseudo-multipoles and single-layer potentials on boundary surface. Scientific challenges stem from the need to calculate higher-order derivates of the measurand required for the pseudo-multipoles extraction from field data. This boots the requirements (acquisition and read out noise) of the digital integrators, the mechanical stability of the bench and transport system. Other challenges stem from the coil design. The non-negligible thickness and the short length of the search coils impacts on the post-processing analysis due to convoluted signals.

Applying the concept of pseudo-multipoles, the field distribution in the end-regions of the magnet can be reconstituted from measurements on the boundary surface. This is possible using a short, iso-perimetric coil.

My first year of research activity has been mostly focused on the study of the mathematical model for the pseudo-multipoles and on the validation of this model.

In a simply-connected, cylindrical domain, free of magnetized material and current sources, the field components can be calculated from a magnetic scalar potential obeying the Laplace equation. An engineering solution by Fourier-Bessel series has been found and developed. Furthermore, an easy implementable solution for the field components in cylindrical coordinates was found. A suitable post-processing tool was developed based on the theory of pseudo-multipoles, as well as field reconstruction from boundary data.

The mathematical model has been validated comparing the y-component of the field along the magnet axis, calculated by the CERN field computation program (ROXIE). The results show that the normalized root-mean-square deviation (NRMSD) is in the acceptable range.

Within a collaboration frame with the magnetic measurement section of CERN's TE department, we have started to design and construct the measurement system composed of high-precision mechanics with integrated real-time automatic control and drive system, encoders, and measurement transducers with iso-perimetric search coils.

As a proof of principle, a new translating system, based on the existing measurement system and using the rotating-coil scanner as search coil, has been developed. Moreover, the study and design of the new transducer with iso-perimentric search coils has been already started. The main challenge is to have high resolution for high harmonic order and no sensitivity for z-component magnetic field.

Next steps of my research activities will be to prove the isoperimetric-coil method, applying the developed mathematic model, by means of real measurements in the reference dipole. Hence, it will be possible to build the complete 3D map of the magnetic field in the magnet aperture. After that, the final design of the new measurement system and a C++ code to measure and compute automatically the magnetic field will be realized.

Therefore, the research activity will lead to:

- improve the mathematical model of the pseudo-multipoles analysis,
- design and assembly a new sensor for the pseudo-multipoles analysis,
- assembly a new high-performance and flexible measurement system
- metrological characterize the overall system.

4. Product

Poster for the 2nd PACMAN workshop, Poster title: "*A Magnetic Measurement System for Extracting Pseudo-Multipoles in Accelerator Magnets*", held in Debrecen (Hungary) June 2016.

5. Tutorship

Competitive doctoral program at CERN of Genève. I spent the whole first year at CERN.

6. Credit summary

Student: Gianni Caiafa gianni.caiafa@unina.it

Tutor: Pasquale Arpaia pasquale.arpaia@unina.it

Cycle XXXI

	Credits year 1								Credits year 2								Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Total	Check
Modules	20	4	0	0	10	9	0	23	10							0	0							0	23	30-70
Seminars	5	0	0	0.5	3	0.5	6.2	10	5							0	0							0	10	10-30
Research	35	0	3	7	10	7	7	34	45							0	60							0	34	80-140
	60	4	3	7.5	23	17	13	67	60	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	67	180

Year	Lecture/Activity	Type	Credits	Certification
1	Field Computation and Magnetic Measurements for Accelerator Magnets	Ad hoc module	4	x
1	Language course- French A1	External Module	7.5	x
1	Electrical Approval Certificate	External Module	2.5	x
1	Misure per l'Automazione e Produzione Industriale	MS Module	9	x
1	The Magnetic Model of the LHC at 6.5 TeV	Seminar	0.5	x
1	Magnetic system and magnetic measurements in EFFL's TCV tokamak	Seminar	0.5	x
1	PACMAN Project: a Study on New Solutions for the High-accuracy Alignment of Accelerator Components	Seminar	0.5	x
1	The translating fluxmeter prototype: early results, Research and development on stretched –wire systems for magnetic measurements	Seminar	2	x
1	Stray Field Measurements	Seminar	0.5	x
1	Seminario di Eccellenza Italo Gorini 2016	Doctoral School	3.7	x
1	Scientific writing	External Seminar	2	x
1	3D computation of magnetic fields and induced currents in hysteretic media with time-periodic sources	External Seminar	0.5	x