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 – Second 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

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b. Seminars

- "*AWAKE Beam Commissioning*", organized by Janet Susan Schmidt, CERN, December 1th 2016, (0.5 CFU)
- "*Identification of Complex Dynamical Systems with Neural Networks*", organized by Hans-Georg Zimmermann, CERN, December 5th – 6th 2016, (1 CFU)
- "*GaN for power applications: devices and switching performances*", organized by prof. Ettore Napoli, UNINA DIETI, December 15th 2016, (0.5 CFU)
- "*ADS Workshop" organized by Dr Giulia Bellodi, CERN, February 7th – 9th 2017, (3 CFU)*
- "*Tokamak Energy - A Faster Way to Fusion*", organized by Mr. Paul Noonan, CERN, February 21th 2017, (1 CFU)
- "*How to Organise and Write a Scientific Rebuttal*", organized by Prof. Pasquale Arpaia, UNINA DIETI, March 10th 2017, (0.4 CFU)
- "*Italo Gorini 2017*", Doctoral Summer School promoted by the Italian "*Electrical and Electronic Measurement*" (GMEE), Catania, August 28th – September 1th 2017, (3.7 CFU)
- "*EUCAS 2017 European Conference on Applied Superconductivity*", organized by CERN, September 17th – 21th 2017, (5 CFU)
- "*High temperature superconductors: How to build powerful magnets using these imperfect conductors?*", organized by Tengming Shen (Lawrence Berkeley National Laboratory), CERN, September 26th 2017, (1 CFU)
- "*Lesson learned the 2-m Nb3Sn 11 T Model Dipole Magnets - From coil fabrication to magnet tests*", organized by Emelie Nilsson, CERN, October 17st 2017, (0.5 CFU)

c. External courses

- External Module, "*English language course – B2*", April, (7.5 CFU)
- External Module, "First Aider Course", October, (1.5 CFU)

3. Research activities

Title: Rotating Coil Sensor for Transversal Field Harmonics

Measuring the magnetic field in accelerator magnet it is often sufficient to measure the integrated, transversal field components and the integrated strength, reach a high precision on the order of one unit in 10000. If the beam has a large acceptance, the beta function changes rapidly, there are space charge limits, or the measurements shall be used for track reconstruction, the precision knowledge of the **local field distribution** is required.

The local field distribution can be measured using the standard method of mapping with a 3-axis hall-sensors positioned in the all aperture volume by high-precision stages. However, these mappings are time consuming and limited in accuracy due to calibration errors, thermal drifts and planar effects. A 3D field map could be calculated from 2D surface measurements using a 3D axis hall probe mounted on a rotating shaft (Takeda, 2013). An alternative method is measuring the longitudinal field profile using a flux-meter. Running it along all the magnet`s length is possible to measure the local multipoles. A method based on rotating coil transducers has been presented in (Arpaia, 2015).

My second year of research activity has been concentrated on the technical issues associated to the rotating field transducers. In fact, it turns out that the classical coil design and compensation schemes cannot be used because they would implicitly rely on scaling laws derived from the radial field dependence in two dimensional domains, i.e., in the center of a long magnet. Indeed, some measurements have established that the z field component interacts with the standard rotating coil.

In order to solve the technical issues cited, a new sensor design has been developed, based on the pseudo-multipole theory (Russenschuck, 2017). R&D efforts were required to develop a mathematical model that links magnetic measurements with pseudo-multipoles, to design and procure a short sensor with no sensitivity for the longitudinal field component and sensitivity for measuring high-order harmonics with a resolution of on unit in 10000. The design was performed by ROXIE and MatLab optimizing the position of each tracks of the **iso-perimetric, saddle-shaped** coil.

Few technologies were considered for the sensor production. At the end, the flexible printed circuit technology was chosen.

Considering the design of the coil, some sensitivity analysis were performed to calculate the tolerance needed on the production process, in order to keep the quality factor high, "**bucking ratio**". A challenge was to design the layer jumps between the four layers, minimizing the differences between the theoretically best and the real paths.

The design process has involved the full transducer. In fact, it will be assembled with an iso-perimetric induction-coil, a standard radial coil, two hall probes and a temperature sensor for reference and crosscalibration. The measurement setup for proof of principle has been designed to have all the needed measurement to validate the new sensor design on one transducer.

Next steps of my research activities will be to assemble the transducer based on the isoperimetric-coil, calibrate the sensors and prove the no sensitivity to the z-component of the magnetic field. Some tests will be performed in a solenoid (in this case the main field is along z) and some others on the fringe field area of normal conducting magnets. As direct application of the new sensor, some measurements will be performed on the new superconducting magnet for HI-LUMI HL-LHC Project in order to measure the longitudinal field profile.

Therefore, the research activity will lead to:

- validate the design of the iso-perimetric coil,
- proof the performance of the iso-perimetric coil for calculating the pseudo-multipoles,
- assembly a new high-performance and flexible measurement system,
- metrological characterize the overall system,
- measure the new superconducting magnet for HI-LUMI HL-LHC Project.

4. Product

Presentation for the International Magnetic Measurement Workshop (IMMW20). Presentation title: "*Design of an Iso-Perimetric Coil for a Transversal Field Scanner*", held in Diamond Light Source, Oxfordshire (UK) June 2017.

Presentation for PhD Gorini School. Presentation title: "*Rotating Coil Sensor for Transversal Field Harmonics*", held in Catania, Sicily (Italy) August 2017.

5. Tutorship

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

6. Credit summary

Student: Gianni Caiafa — gianni.caiafa@unina.it
Tutors: Pasquale Arpaia - Stephan Russenschuck — pasquale.arpaia@unina.it, stephan.Russenschuck@cern.ch
Cycle XXXI

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20	4	0	0	10	9	0	23	10	0	0	7.5	0	0	1.5	9	0							0	32	30-70
Seminars	5	0	0	0.5	3	0.5	6.2	10	5	2	3.5	0.4	0	0	10	16	0							0	26	10-30
Research	35	0	3	7	10	7	7	34	45	10	5	2	10	10	10	47	60							0	81	80-140
	60	4	3	7.5	23	17	13	67	60	12	8.5	9.9	10	10	22	72	60	0	0	0	0	0	0	0	139	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
2	AWAKE Beam Commissioning	Seminar	0.5	x
2	Identification of Complex Dynamical Systems with Neural Networks	Seminar	1	x
2	GaN for power applications: devices and switching performances	Seminar	0.5	x
2	ADS Workshop	External Seminar	3	x
2	Tokamak Energy - A Faster Way to Fusion	Seminar	0.5	x
2	How to Organise and Write a Scientific Rebuttal	Seminar	0.4	x
2	Language course- English B2	External Module	7.5	x
2	Seminario di Eccellenza Italo Gorini 2016	Doctoral School	3.7	x
2	EUCAS 2017 European Conference on Applied Superconductivity	External Seminar	5	x
2	High temperature superconductors: How to build powerful magnets using these imperfect conductors?	Seminar	1	x
2	Lesson learned the 2-m Nb3Sn 11 T Model Dipole Magnets - From coil fabrication to magnet tests	Seminar	0.5	x
2	First Aider Course	External Module	1.5	x

Bibliography

Arpaia, P. a. (2015). A rotating coil transducer for magnetic field mapping. *Journal of Instrumentation*, P06006.

Russenschuck, S. (2017). Rotating-and translating-coil magnetometers for extracting pseudo-multipoles in accelerator magnets. *COMPEL-The international journal for computation and mathematics in electrical and electronic engineering*, 00--00.

Takeda, H. a. (2013). Extraction of 3D field maps of magnetic multipoles from 2D surface measurements with applications to the optics calculations of the large-acceptance superconducting fragment separator BigRIPS. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 798--809.