PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Vincenzo Paolo Loschiavo

XXIX Cycle

Training and Research Activities Report – Third Year

Tutor: Prof. Ing. Raffaele Albanese

1. Information

Vincenzo Paolo Loschiavo

M.Sc. Degree in Mechanical Engineering – University of Naples Federico II

ITEE Ph.D. XXIX Cycle

Grant

Tutor: Prof. Eng. Raffaele Albanese

2. Study and Training activities

During the third ITEE Ph.D. year, I had the opportunity to attend different interesting seminars with the aim to improve my previous knowledge and my skills. In particular:

- "Electromagnetic consequences of violent instabilities in tokamaks – part 1", Prof. V. D. Pustovitov, 30 January 2017, 15:00-16:30 (DIETI)
- - "Electromagnetic consequences of violent instabilities in tokamaks – part 2", Prof. V. D. Pustovitov, 3 February 2017, 15:00-17:00 (DIETI)

Moreover, I took part in different events organized by the Scuola Nazionale Dottorandi di Elettrotecnica "Ferdinando Gasparini" in cooperation with the IEEE Italy Section (23-30 October 2016) in which I had the opportunity to attend different lectures on the topics:

- Principles and Techniques of Electromagnetic Compatibility - C. Christopoulos (Univ. of Nottingham, UK)
- Magnetic materials for energy applications - F. Fiorillo (Istituto Nazionale di Ricerca Metrologica, Torino, Italy)
- Artificial Neural Networks: Architectures and Applications - G. Grassi (Univ. del Salento, Lecce, Italy)
- Nonlinear Circuit Dynamics and Chaos: introduction and Frequency Synthesis - P. Kennedy (Univ. College Cork & Tyndall National Institute, Cork, Ireland)
- Deterministic and stochastic optimization in electromagnetism and circuit theory - C. Magele (Graz University of Technology. Inst. Fund. and Theory in El. Eng.)
- Zero-dimensional, one-dimensional, two-dimensional and three-dimensional nanostructured materials for electrical engineering - G. Miano (Univ. di Napoli Federico II, Italy)
- Superconducting materials and their applications - R. Vaglio (Univ. di Napoli Federico II, Italy)
- Computational electromagnetics: formulations, numerical solutions and examples of application - F. Villone (Univ. di Cassino e del Lazio meridionale, Cassino, Italy)

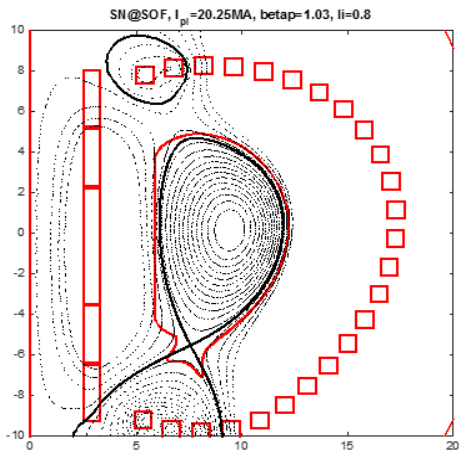
In the table, there is a short credits recap.

	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	21			3		3	5	**11**	15		6		1		12	**19**								**0**	**30**	30-70
Seminars	5	0.4	0.8		1	0.2	2	**4.4**	5	0.8	0.2		0.4		0.4	**1.8**					8.4		0.6	**9**	**15**	10-30
Research	34	10	8	8	8	6	0	**40**	40	10	6	10	10	10	0	**46**		10	10	8	5	8	8	**49**	**135**	80-140
	60	10	8.8	11	9	9.2	7	**55**	60	11	12	10	11	10	12	**67**	60	10	10	8	13	8	8.6	**58**	**180**	180

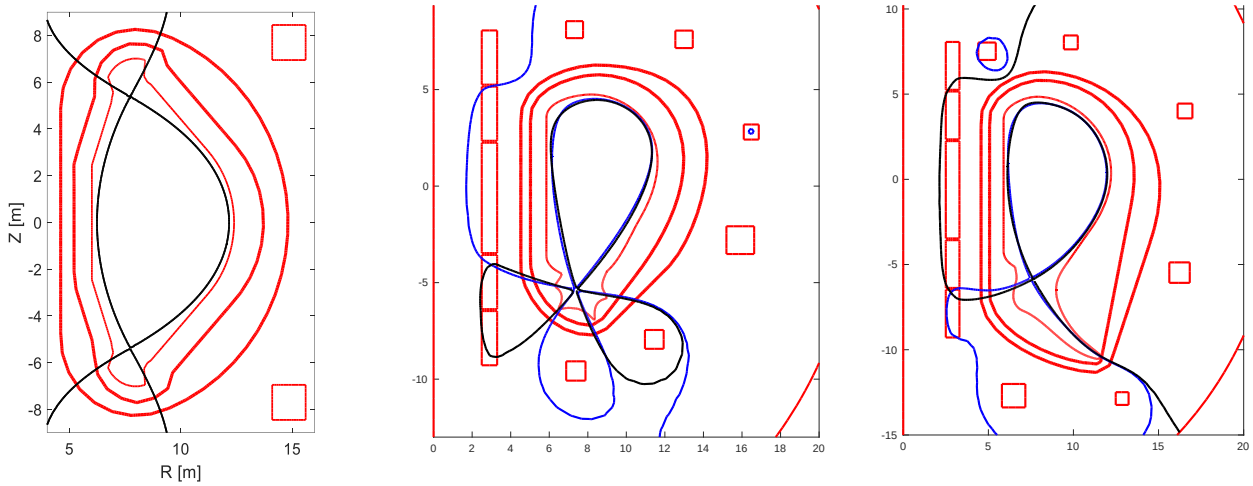
3. Research activity

The research activity proposed during the first PhD year by my tutor - that I accepted enthusiastically - is *addressing the power exhaust and particles in the next generation fusion reactors*. This topic is regarded as one of the ultimate challenges for the design of DEMO reactor. During my first ITEE PhD year, we identified the *Strike-Point Sweeping* as one of the most promising techniques for spreading the huge heat load impinging on the material surfaces (PFCs – Plasma Facing Components). Moreover, during the second PhD year further analyses have been carried out in order to address the thermal fatigue issue, a phenomenon originating in the strike-point sweeping and strictly related to a heat load periodically changing in time. At the same time, I also worked, all over the year, with Prof. Roberto Ambrosino and my tutor on the "Optimization of PF coils in DEMO tokamak".

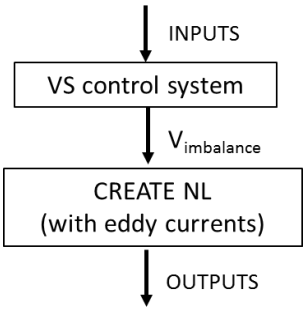
During the third ITEE PhD year, the Optimization procedure just mentioned has been developed in order to take into account the forces acting on the coils generating the different plasma magnetic configurations. Therefore, starting from a redundant PF coils configuration, we demonstrated that it is possible to produce a given plasma equilibrium reducing the number of coils to a set optimizing the currents and respecting the force constraints.

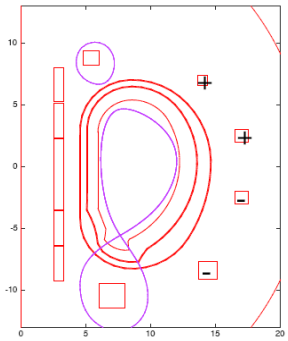


This Optimization procedure has been used to *design Alternative Magnetic Plasma Configurations* for the DEMO fusion power plant. In fact, Alternative Magnetic Plasma Configurations represent candidate solutions in addressing the power exhaust and particles in the next generation fusion reactors since they are able to spread, in different ways, the heat load impinging on the plasma facing components.



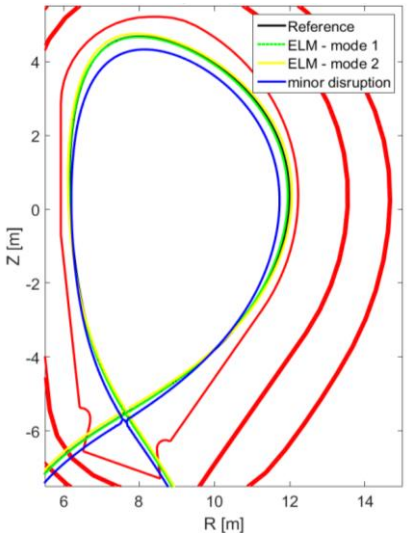
Once the optimized Alternative Magnetic Plasma Configurations have been designed, an assessment of the vertical stability properties have been carried out. In particular, for the different plasma configurations, open loop non-linear dynamic simulations have been produced taking into account the eddy currents originating in the passive structures and the presence of the ports (needed for the device maintenance).

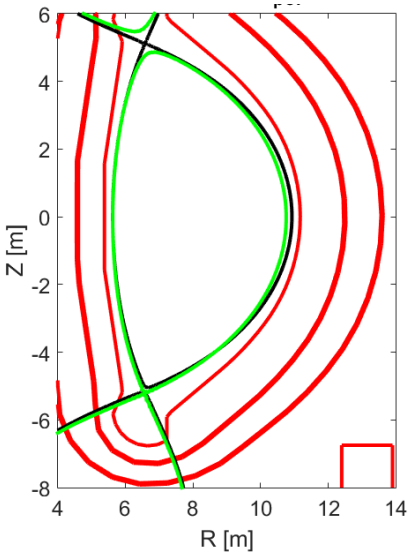




The *Vertical Stability analysis*, mainly focused on the comparison between the DEMO Single Null (SN) and Double Null (DN) magnetic configurations, has clearly shown that:

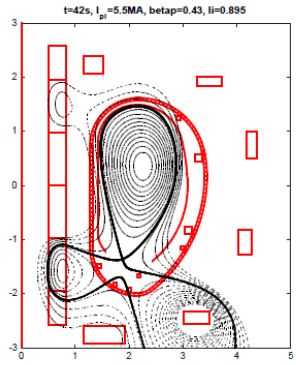
- the growth rate (γ) of the SN is always less than the DN configurations;
- the total power on the imbalance circuit (P_{TOT}) for DN configurations is considerable less than in the SN case;
- for the DN configuration the vertical displacement of the plasma is much lower than the SN.

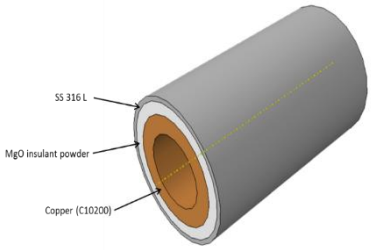


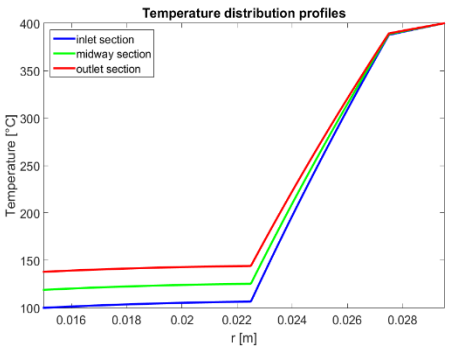


Part of this main activity has been carried out during 4 months (April – July 2016) and one additional week (13-19 November) spent at the Max Planck Institut fur PlasmaPhysics – EUROfusion (Garching - Munich) working with PhDs Francesco Maviglia and Ronald Wenninger. In those days, I had also the possibility to meet relevant engineers (Gianfranco Federici, Eberhard Diegele, Christian Bachmann) working on the DEMO reactor design and those meetings and work-shops resulted in helpful collaborations.

I also worked, all over the year, with Prof. Roberto Ambrosino and my tutor on the Alternative Magnetic Configurations for the Divertor Tokamak Test (DTT) facility, an Italian project proposal for a facility able to investigate candidate solutions to the power exhaust issue for the divertor of a fusion power plant. I worked also on the design of the in-vessel coil cooling system, being proudly among the project proposal contributors.







4. Products

During this year, I was involved in different Journal Papers:

- "DTT: a divertor tokamak test facility for the study of the power exhaust issues in view of DEMO", Nuclear Fusion 57 (2017) 016010 (13pp), Published 11 October 2016 (doi:10.1088/0029-5515/57/1/016010)
- "The DEMO wall load challenge", Nuclear Fusion 57 (2017) 046002 (11pp), Published 9 February 2017 (doi:10.1088/1741-4326/aa4fb4)
- "TEST OF A NOVEL TECHNIQUE FOR THE RECONSTRUCTION OF 3D MAGNETIC FIELDS IN TOKAMAKS", accepted for publication in the International Journal of Applied Electromagnetics and Mechanics, Accepted on 30 January 2017
- "The DTT device: Poloidal Field Coil Assessment for Alternative Plasma Configurations", accepted for publication in the Journal of Fusion Engineering and Design, Accepted on 29 January 2017

5. Conferences and Seminars

During this year, I was involved in different Conference Papers:

- "The DEMO wall load challenge", International Conference on Plasma Surface Interactions in Controlled Fusion Devices, Rome, May 30 – June 3, 2016 (http://www.psi2016.enea.it/index.php/component/content/category/2-uncategorised)
- "TEST OF A NOVEL TECHNIQUE FOR THE RECONSTRUCTION OF 3D MAGNETIC FIELDS IN TOKAMAKS", 14thInternational Workshop on Optimization and Inverse Problems in Electromagnetism September 13 – 15, 2016, Rome, Italy (http://oipe2016.uniroma3.it/)

Respectively presented by R. Wenninger and S. Minucci.

6. Activity abroad

I spent 4 months (1 April – 31 July 2016) and one additional week (13-19 November 2016) in the Max Planck Institut for Plasma Physics – EUROfusion (Garching – Munich). In those days, I worked

also with F. Maviglia, G. Federici, R. Wenninger (EUROfusion) on the DEMO reactor design. Eberhard Diegele, Christian Bachmann and others engineers and physicists.

7. Tutorship

I have been involved – 20 hours – in lectures and practice exercises proposed to the students of the "Elettrotecnica", "Introduzione ai Circuiti" and "Plasmi e fusion termonucleare controllata" courses held by Professors R. Albanese and M. de Magistris.