PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Bianca Caiazzo

Cycle: XXXV

Training and Research Activities Report

Year: First

student signature :

Tutor: Prof. Stefania Santini *tutor signature*

Co-Tutor: Prof. Amedeo Andreotti

Date: October 21, 2020

1. Information:

- **PhD student: Bianca Caiazzo**
- **DR number: DR993884**
- **Date of birth: 24/08/1994**
- **Master Science degree: Management Engineering**
- **University: University of Naples Federico II**
- **Doctoral Cycle: XXXV**
- **Scholarship type: *UNINA***
- **Tutor: Prof. Stefania Santini**
- **Co-tutor: Prof. Amedeo Andreotti**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Intelligenza artificiale ed etica: la ricerca in IA alla prova delle sfide etiche	Course	8	1.6	6/12/2019	Dott. Roberto Prevete (DIETI)	N
A dynamic and probabilistic orienteering problem	Seminar	1	0.2	8/11/2019	Prof. Claudio Sterle	Y
Flexible two-echelon location-routing for supply networks	Seminar	1	0.2	8/11/2019	Prof. Claudio Sterle	Y
Lo spazio cibernetico nel dominio bellico	Seminar	2	0.4	15/11/2019	Prof. Guglielmo Tamburrini	Y
Deep learning Onramp	Seminar	2	0.4	21/11/2019	Prof. Carlo Sansone	Y
L'ingegnere nel business dell'energia	Seminar	5	1	28/11/2019	Dott. Annamaria Buonomano (DII)	Y
Marked point processes for object detection and tracking in high resolution images: application to remote sensing data	Seminar	1.5	0.3	02/12/2019	Prof. Giuseppe Scarpa	Y

Safety Critical Systems for railway traffic Management	**Course**	**20**	**3.3**	**10/01/2020-27/01/2020**	**Prof.Mazzeo; Prof.Mazzocca (DIETI)**	**Y**
Cybersecurity and fuzzing for robots, blockchain, and more	**Seminar**	**1**	**0.2**	**13/01/2020**	**Dott. Roberto Natella**	**Y**
Matlab Foundamentals	**Course**	**20**	**2**	**20/02/2020 - 24/03/2020**	**Prof. Agostino De Marco; DIETI and SPSB UNINA**	**Y**
Scientific Programming and Visualization with Python	**Course**	**20**	**2**	**27/02/2020 -4/03/2020**	**DiSt department -SPSC UNINA; Dott. Ing. Alessio Botta**	**Y**
Computational Biology: large scale data analysis to understand the molecular bases of human diseases	**Seminar**	**1**	**0.2**	**09/04/2020**	**Prof. Michele Ceccarelli (DIETI)**	**Y**
Elettromagnetismo e salute	**Seminar**	**1**	**0.2**	**09/04/2020**	**Prof. Rita Massa**	**N**
Webinar: "How to get published with IEEE"	**Seminar**	**2**	**0.4**	**20/04/2020**	**Dott.ssa Alessandra Scippa (DIETI)**	**Y**
Innovation Management, entrepeneurship and intellectual property	**Course**	**20**	**5**	**5/05/2020-19/06/2020**	**Prof. Pierluigi Rippa and StartCup Campania 2020**	**Y**
Model Predictive Control	**Course**	**23**	**4.6**	**3/06/2020-10/06/2020**	**Prof. Alberto Bemporad, Scuola IMT Alti Studi Lucca**	**Y**
Big data analytics and business intelligence	**Course**	**-**	**6**	**II semester a.a.2019-2020**	**Prof. Antonio Picariello; Prof. Vincenzo Moscato**	**Y**

Access the eLearning library on IEEE Xplore	**Seminar**	**1**	**0.2**	**4/05/2020**	**Dott.ssa Alessandra Scippa (DIETI)**	**Y**
Large scale training of Deep Neural Network	**Seminar**	**2**	**0.4**	**6/05/2020**	**Prof. Carlo Sansone**	**Y**
Design e nuove tecnologie. Possibili scenari per fronteggiare l'emergenza	**Seminar**	**1**	**0.2**	**11/05/2020**	**Part of the Innovation Village 2020 series of webinars**	**Y**
La programmazione europea e la ricerca. Nuovi scenari della programmazione europea dopo il 2020	**Seminar**	**2**	**0.4**	**13/05/2020**	**Part of the Innovation Village 2020 series of webinars**	**Y**
Health 4.0-La rapidità della medicina e la velocità del cambiamento del nostro mondo organizzato da Università degli studi di Napoli Federico II	**Seminar**	**2**	**0.4**	**14/05/2020**	**Part of the Innovation Village 2020 series of webinars (UNINA)**	**N**
Realtà virtuale e salute reale. Health 4.0-Dal bit alla mente: spazi virtuali per la salute	**Seminar**	**2.5**	**0.5**	**15/05/2020**	**Part of the Innovation Village 2020 series of webinars**	**N**
Planning 5G under EMF constraints: challenges and opportunities	**Seminar**	**2**	**0.4**	**18/05/2020**	**Prof. Luca Chiaraviglio; Dr.A.Cacciapuoti; Dott.M.Calefi**	**N**
Joint design of optics and post-processing algorithms based on deep learning for generating advanced imaging features	**Seminar**	**2**	**0.4**	**19/05/2020**	**Part of the Signal Processing and Computational image formation (SPACE), by IEEE SPS**	**N**
Virtual seminars on sensing	**Seminar**	**4**	**0.8**	**20/05/2020**	**Prof. Carlo Forestiere, DIETI, and Plasmonica**	**Y**

Machine Learning	**Course**	**18**	**3.6**	**6/07/2020-17/07/2020**	**ITEE-ICTH**	**Y**
Intelligenza Artificiale	**Course**	**-**	**6**	**II semester a.a.2019/2020**	**Prof. Flora Amato**	**Y**
Time-Delay and Sampled-Data Systems	**Doctoral School**	**21**	**3**	**7/09/2020-11/09/2020**	**EECI 2020-International Graduate School on Control, Prof. Emilia Fridman; Prof. Pierdomenico Pepe**	**Y**

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	1.6	2.5	5.9	0	10
Bimonth 2	3.3	0.2	6.5	0	10
Bimonth 3	4	0.8	5.2	0	10
Bimonth 4	15.6	3.7	4	0	23.3
Bimonth 5	9.6	0	5	0	14.6
Bimonth 6	3	0	7	0	10
Total	**37.1**	**7.2**	**33.6**	**0**	**77.9**
Expected	**30-70**	**10-30**	**80-140**	**0-4.8**	

3. Research activity:

Nowadays, energy demand is expected to increase by 34% up to 2035, with 20% more CO_2 emissions from fossil fuels, among which 60% is emitted by coal. Therefore, CO_2 emissions from power production account for 2/3 of man-made greenhouse gases, increasing concerns about global warming[1]. These factors have motivated the emergence of various kinds of renewable energy sources (RES) including solar panels and wind turbines, thus reducing pollution and power transmission losses, as well as being more economical solutions due to lower transmission costs[2].

Therefore, in recent year, we are moving towards alternative solutions in order to replace traditional and conventional electric grids and power sources with more sophisticated and advanced mechanisms, enclosed in “Smart Grids” idea. Moreover, breaking large-scale electric grids into smaller and connected systems, actually there is a transition from large centralized power plants to small distributed renewable power plant, i.e. the so called Microgrid (MG) [3].

In this context, a MG integrates distributed generation (DG) units, energy storage systems (ESSs) and local loads, so to significantly improve reliability, efficiency and flexibility of the electrical network.

Aside from the available generation facilities, MGs can operate in two different ways: islanded and grid-connected mode. While in the latter case the MG dynamics is dominated by the main grid, in islanded mode efficient control strategies are needed to guarantee both frequency and voltage restoration to the reference value, as well as optimal real and reactive power dispatch among flexible loads, ESSs and DGs. Therefore, frequency, voltage, and power quality are the three main issues that need to be considered in stability analysis and require a proper control scheme to meet acceptable standards and safe operation ranges.

The most common instance to properly design the architecture for these electrical grids is based on Multi-Agent System (MAS) framework [4], which guarantee the implementation of distributed cooperative control strategies in order to better meet the highly dynamic behaviour of a MG. In so doing, these future electrical grids will be restructured as a cyber-physical system which components not only have to carry optimal power flow, but also have to transmit data for achieve different control objectives, i.e. guarantee a desired dynamic behaviour for each single node, while coordinating at the same time the overall behaviour of the ensemble.

Many researchers have focused their works on MAS framework in order to solve the frequency/voltage restoration and power sharing control problems for islanded MGs by leveraging synchronization, consensus and coordination of networked dynamical systems theory. In this context, the synchronization problem has been addressed at first without considering the presence of a leading node, so all nodes are commanded to converge toward a common evolution which is not prescribed [5]. Cooperative tracking control or leader synchronization, has been then studied by adding a leader that communicates with a group of neighbours to impose a desired behaviour, e.g. the voltage and frequency references magnitude.

To reach the frequency and voltage cooperative synchronization goals, electrical nodes, equipped with smart controller devices, share information through dedicated busses or wireless communication. Delays in information acquisition and transmission are unavoidable in realistic scenarios like this, where the time-delay itself might obey its own dynamics (which possibly depend on the communication distance, total computation load and computation capability). Thus, in all practical cases, delays cannot be assumed as uniform (homogeneous) and constant, but they have to be considered as time-varying functions depending from the specific communication link under investigation (multiple, or heterogeneous, time-varying delays)[6]. However, although in practical implementation the communication time-delays cannot be ignored, few papers address this issue in the MG control context.

Besides robustness with respect to communication time-delays, another important issue is related to the achievement of MG stability in a finite-time interval. Indeed, due to sensitive loads, it is desirable to speed-up the synchronization process of the overall MG network, reaching the set-point (in terms of both frequency and voltage reference values) in a finite-time[7], while ensuring prescribed transient behaviour for the whole MG (i.e. the state trajectories have to result always bounded during each transient phase).

In this context, my study during this year focuses on the problem of frequency and voltage cooperative synchronization in the presence of time-varying communication delays and design of control strategies able to guarantee the achievement of prescribed frequency and voltage set-point imposed by a leading agent, while taking into account also worst case scenarios where hard load fluctuations occur due to sudden changing into the surrounding environment.

One of the distributed solutions proposed in my work leverages on the Lyapunov-Krasovskii theory for time-delay systems and Finite-Time stability tools, so to provide the robustness of the proposed control approach in guaranteeing the achievement of voltage reference value for the entire MG system with prescribed transient and steady-state performances, despite the presence of communication time-delays, unavoidable load variations and unmodeled dynamics.

More specifically, by exploiting the Lyapunov-Krasovskii method, it is proved that the proposed distributed cooperative control strategy can guarantee that each DG tracks the desired reference behaviour as imposed by a virtual leader interacting with its neighbours and assumed to be globally reachable (i.e. there is a path, that can be directed or not, that links the leading agent with the others)[8].
The derived robust finite-time and delay-dependent stability conditions are expressed as a set of Linear Matrix Inequalities (LMIs), whose solution allows the proper tuning of the control gains, as well as the threshold for the state trajectories during each transient phase. Some numerical examples are carried out on the well-known benchmark of IEEE 14-bus Test System and show the effectiveness of the approach.

References:

[1] British Petrolium Company (2015) The energy challenge and climate change. BP Sustainability Report. https://www.bp.com/content/dam/bp/pdf/about-bp/energy-challenge-climate-change.pdf. Accessed 3 July 2018

[2]Abdella, J., & Shuaib, K. (2018). Peer to peer distributed energy trading in smart grids: A survey. *Energies*, *11*(6), 1560.

[3] Wen, G., Hu, G., Hu, J., Shi, X., & Chen, G. (2015). Frequency regulation of source-grid-load systems: A compound control strategy. *IEEE transactions on industrial informatics*, *12*(1), 69-78.

[4] de Azevedo, R., Cintuglu, M. H., Ma, T., & Mohammed, O. A. (2017). Multiagent-based optimal microgrid control using fully distributed diffusion strategy. *IEEE Transactions on Smart Grid*, *8*(4), 1997-2008.

[5] Lewis, F. L., Zhang, H., Hengster-Movric, K., & Das, A. (2013). *Cooperative control of multi-agent systems: optimal and adaptive design approaches*. Springer Science & Business Media.

[6] Fridman, E. (2014). *Introduction to time-delay systems: Analysis and control*. Springer.

[7] Dehkordi, N. M., Sadati, N., & Hamzeh, M. (2016). Distributed robust finite-time secondary voltage and frequency control of islanded microgrids. *IEEE Transactions on Power Systems*, *32*(5), 3648-3659.

[8] Hu, J., & Hong, Y. (2007). Leader-following coordination of multi-agent systems with coupling time delays. *Physica A: Statistical Mechanics and its Applications*, *374*(2), 853-863.

4. Research products:

- Andreotti, A., Caiazzo, B., Petrillo, A., Santini, S., & Vaccaro, A. (2019). Decentralized Smart Grid Voltage Control by Synchronization of Linear Multiagent Systems in the Presence of Time-Varying Latencies. *Electronics*, *8*(12), 1470 (**Published:** 3 December 2019)

- Andreotti, A., Caiazzo, B., Petrillo, A., Santini, S., & Vaccaro, A. (2020, June). Robust Finite-time Voltage Restoration in Inverter-Based Microgrids via Distributed Cooperative Control in presence of communication time-varying delays. In *2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)* (pp. 1-6). IEEE **(Published)**

5. Conferences and seminars attended

a. Details:
2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), 9-12 June 2020, online conference

b. Presentation made:
Presentation of the paper "Robust Finite-time Voltage Restoration in Inverter-Based Microgrids via Distributed Cooperative Control in presence of communication time-varying delays" at *2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), 9-12 June 2020, online conference*

6. Activity abroad:

7. Tutorship