Bianca Caiazzo

# Modeling and control of electric and energy grids

Tutor: Prof. Stefania Santini
co-Tutor: Prof. Amedeo Andreotti

Cycle: XXXV
Year: Second

Academic Year 2020-2021

# BACKGROUND & INFO

- MSc degree in Management Engineering, University of Naples Federico II
- Working team: DAiSy Lab
- Tutor: Prof. Stefania Santini
- Co-Tutor: Prof. Amedeo Andreotti
- PhD start date: Academic Year 2019-2020
- Scholarship type: “UNINA”

# RESEARCH TOPIC (1/2)

- Designing distributed cooperative control protocols for autonomous Multi-Agent System (MASs) aiming at reaching a prescribed common group behavior.

- Application to Microgrids, which have received great attention due to their ability in integrating renewable Distributed Generation units (DGs), thus exploiting their environmental benefits, as well as their economical, resilient and reliable advantages.

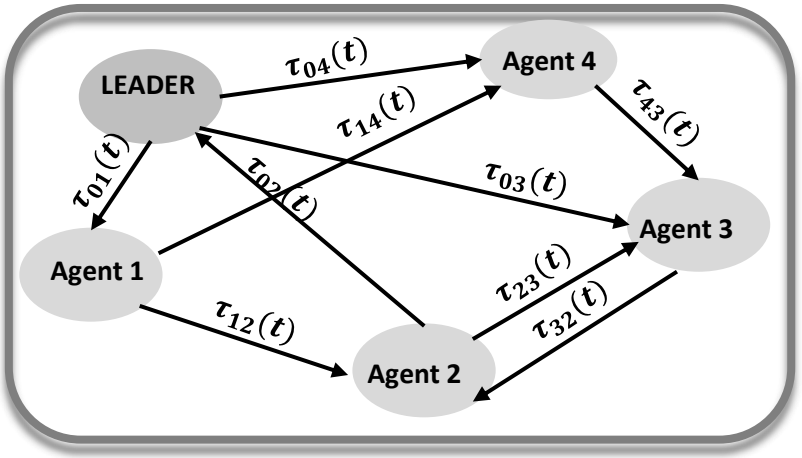
# RESEARCH TOPIC (2/2)

- Cooperative control of agents, interacting among them and with the environment via communication network, becomes a crucial task to guarantee the achievement of state/output consensus.

- The aim of the research is to design proper control strategies for distributed cyber-physical systems, taking into account model mismatches and communication constraints, such as time-delays in information exchanges and communication network bandwidth problems.

The objective is to tailor theoretical results with respect to practical problems arising in modern energy grids applications, e.g. Microgrids and smart innovative power networks, which could include also renewable energies sources according to "Green Growth" frame in Horizon 2020 program.

MAS ARCHITECTURE



# My 2nd Year: Study & Training Activities

- Focus of my second year activity has been modelling and control cyber-physical systems accounting for communication constraints. The idea is to design theoretical tools that can be practically implemented in Networked Control architectures for energy grids in a greening perspective.

**16th IFAC Workshop on Time Delay Systems 2021:**

Presentation of the papers:

a. 'Distributed Sampled-Data PID control for Voltage Regulation in Inverter-based islanded Microgrids using Artificial Delays';
b. 'On the exponential leader-tracking control for high order multi-agent systems via distributed PI strategy in the presence of heterogeneous time-varying delays';

Co-chair of the invited session: 'Recent advance on distributed control of Multi-Agent Systems'.

Attended the *Time-Delay Systems (TDS) Webinar series* organized by International Federation of Automatic Control (IFAC) Working Group on time-delay systems, whose speakers include:

a. Prof. Gàbor Stèpàn, Budapest University;
b. Prof. Miroslav Krstic, University of California San Diego;
c. Prof. Silviu Niculescu, CNRS Laboratory of Signals and Systems
d. Prof. Emilia Fridman, Tel Aviv University, Israel

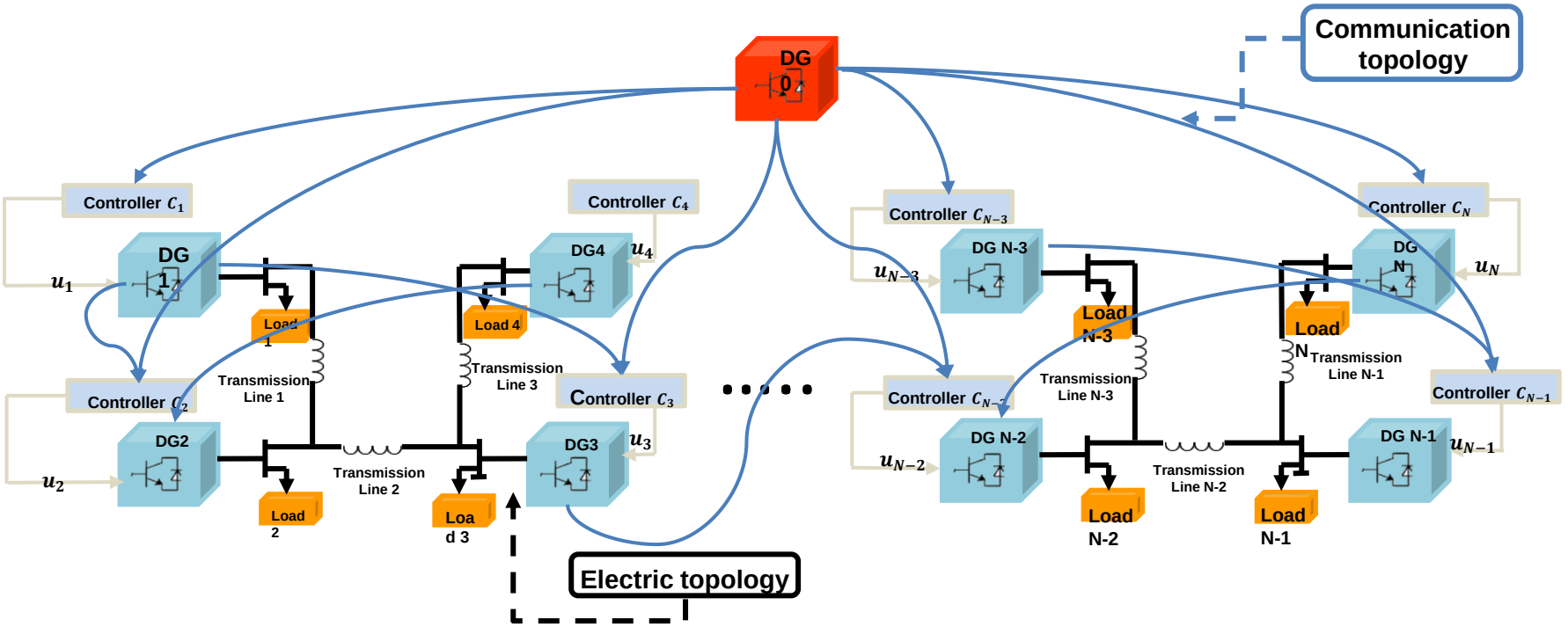
**2021 29th Mediterranean Conference on Control and Automation (MED):**

Presentation of the paper:

'Distributed Robust Finite-Time PID control for the leader-following consensus of uncertain Multi-Agent Systems with communication delay'

# RESEARCH ACTIVITY: PROBLEM STATEMENT

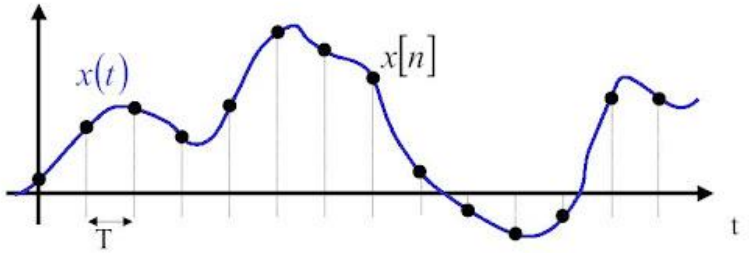
**Schematic representation of Microgrid operating in islanding mode of N+1 DGs and loads connected via the power lines and sharing information through an integrated communication layer.**



# Research Activity: Towards Sampled-Data Control

In this context, distributed control approaches are commonly designed under the very restrictive assumption of ideal and continuous communication among DGs.

However, this hypothesis is not realistic and also may yield to controllers inducing a heavy burden on the communication network. This is not only unrealistic, but also unpractical since the communication bandwidth and channels are limited in real applications.




It follows that there is a growing interest in the study of *sampled-data control* for guaranteeing a reduction of communication traffic via aperiodic communication among DGs.

# RESEARCH ACTIVITY: ARTIFICIAL DELAYS APPROACH

Therefore, during this year it has been explored the sampled-data implementation of derivative-dependent controllers by exploiting the concept of "Artificial delays".

- "Artificial delays" approach allows highlighting that the presence of delay is not always detrimental, thus having stabilizing effect.

The idea is to approximate the derivative action using finite difference approximation as reported in (1), thus obtaining a delayed-dependent controller.

$$\dot{y} \approx \frac{y(t) - y(t-h)}{h} \qquad h > 0 \qquad (1)$$

It has been shown that such approximation preserves the stability if h is small enough.

- The sampled-data implementation of derivative-dependent controllers allows to reduce the amount of control signal used for stabilization.

- The data sampling has been studied using time delay approach.

# YEAR THREE: MY PERIOD ABROAD

- The period abroad has started on October 13, 2021.
- The hosting institution is the Department of Electrical Engineering-Systems at Tel Aviv University (TAU), Israel; the supervisor is Prof. Emilia Fridman, IEEE Fellow.
- Research activity is related to the study of distributed and decentralized sampled-data control strategies for high-order systems by using useful tools of time-delay theory.
- The first results of the collaboration have been published in the paper "Distributed Sampled-data PID Control for Voltage regulation in inverter-based islanded Microgrids using Artificial Delays", proceeding 16th IFAC Workshop on Time Delay Systems 2021.
- For the next third year, it is planned to stay at TAU until the end of April 2022.

# YEAR THREE: OPEN CHALLENGES

**The objective for the last year is to design and test a fully-distributed sampled data control strategy to solve leader-tracking problem in MAS by exploiting artificial delays approach, thus obtaining a significant reduction of the communication burden and improving the efficiency of the entire Networked Control System (NCS).**

**Then, the controller will be applied to solve voltage/frequency and power regulation problems in cyber physical energy systems.**

- **Solving sampling-data control problems via Lyapunov-Krasovskii theory;**
- **Since transmitted signals are sampled in time and are subject to time delays, a predictor-based approach will be considered to compensate both small and large transport delays;**
- **Stability conditions expressed as feasible Linear Matrix Inequalities (LMIs) will be found to guarantee the achievement of global consensus;**
- **Experimental validation in a realistic simulation environment will be carried out by using Simscape tool to emulate a real MG, where both load changing and plug-and-play situations may occur.**

# MY 2ND YEAR: PRODUCTS

- Andreotti, A., Caiazzo, B., Petrillo, A., Santini, S., & Vaccaro, A. (2020). *Hierarchical Two-Layer Distributed Control Architecture for Voltage Regulation in Multiple Microgrids in the Presence of Time-Varying Delays*. **Energies, 13(24), 6507. (Published: 9 December 2020)**;
- Andreotti, A., Caiazzo, B., Petrillo, A., & Santini, S. (2021). *Distributed Robust Finite-Time Secondary Control for Stand-Alone Microgrids With Time-Varying Communication Delays*. **IEEE Access, 9, 59548-59563. (Published: April 16, 2021);**
- Caiazzo, B., Lui, D. G., Petrillo, A., & Santini, S. (2021, June). *Distributed Robust Finite-Time PID control for the leader-following consensus of uncertain Multi-Agent Systems with communication delay.* In 2021 **29th Mediterranean Conference on Control and Automation (MED) (pp. 759-764). IEEE. (Published: June 22, 2021)**;
- Caiazzo, B., Lui, D. G., Petrillo, A., & Santini, S. (2021). *Distributed Double-Layer Control for Coordination of Multi-Platoons approaching road restriction in the presence of IoV communication delays*. **IEEE Internet of Things Journal. (Published: August 05, 2021);**
- Caiazzo, B., Coppola, A., Petrillo, A., & Santini, S. (2021*). Distributed Nonlinear Model Predictive Control for Connected Autonomous Electric Vehicles Platoon with Distance-Dependent Air Drag Formulation*. **Energies, 14(16), 5122. (Published: August 19, 2021);**
- Caiazzo, B., Lui, D. G., Petrillo, A., Santini, S.. *On the exponential leader-tracking control for high-order multi-agent systems via distributed PI strategy in the presence of heterogeneous time-varying delays*. **16th IFAC Workshop on Time Delay Systems 2021. (Accepted);**
- Caiazzo, B., Fridman, E., Petrillo, A., Santini, S.. *Distributed Sampled-data PID Control for Voltage regulation in inverter-based islanded Microgrids using Artificial Delays*. **16th IFAC Workshop on Time Delay Systems 2021. (Accepted);**
- Andreotti, A., Caiazzo, B., Di Pasquale, A., Pagano, M. *On Comparing Regressive and Artificial Neural Network Methods for Power System Forecast*. **AEIT 2021 International Annual Conference, 2th Virtual Edition. (Accepted).**

# THANKS FOR ATTENTION!

## Questions?

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