Ph.D. in Information Technology: Thesis Defenses

February 3rd, 2020

Room 25.1.2 (ex D.2.2), Bldg. n. 25 - h. 11.30

Alessio LA BELLA – XXXII Cycle

“Optimization-based control of microgrids for ancillary services provision and islanded operation”

Advisor: Prof. **Riccardo Scattolini**

Abstract:

The interdisciplinary research presented in this doctoral thesis concerns the investigation and design of control, optimization and identification techniques to facilitate the upcoming energy transition to a more distributed and sustainable electrical system. Microgrids, i.e. small-scale grids incorporating renewable sources, storage systems, controllable loads and dispatchable units, are considered the fundamental bricks of this future electrical paradigm. This is due to their extreme flexibility, being able to operate either connected to the main grid or in islanded mode. The design of dedicated control architectures, allowing the efficient and safe operation of microgrids in these two modes, is the main focus of this doctoral thesis. Precisely, the work is structured in two parts. Firstly, the design of optimization-based control algorithms for coordinating aggregated microgrids to provide external supporting services, usually denoted as ancillary services, is addressed. In fact, the diffusion of intermittent and non-deterministic renewable sources and the increasing world power demand require the cooperation of the different grid elements to ensure the secure operation of the whole electrical system. The second part of the doctoral thesis focuses on the design of novel hierarchical control schemes for the islanded operation. Given the absence of the main grid support, this condition is significantly critical, requiring the efficient management of the local units and the prompt regulation of the internal frequency and voltages. All the designed approaches have been tested through extensive numerical simulations considering real network benchmarks, showing their effectiveness in fostering the integration of microgrids, as well as their beneficial effects for the electrical system.

Enrico TERZI – XXXII Cycle

“Learning-based Model Predictive Control: theory and applications”

Advisor: Prof. **Riccardo Scattolini**

Abstract:

The thesis deals with the problem of controlling and optimizing the behaviour of a system, by means of the design of a suitable regulator, starting from a dataset collected on the system itself. In the literature this issue is generally addressed by clearly distinguishing the model identification and control design phases. On the contrary, Part I of the thesis is devoted to the development of a learning algorithm for identification and control design that considers these two steps in an integrated manner. The model identification phase considers a number of independent models, each tailored to predict the p steps ahead output value, and is based on a Set Membership algorithm. Thanks to these models, it is possible to derive an uncertainty model for a 1-step state space representation directly from data, then applicable to the design of a robust model predictive controller, inspired by the tube-based philosophy.

In Part II of the thesis neural networks, which are meeting an extraordinary popularity in these years, are considered as a surrogate model of the system to be included in an advanced control scheme. In particular, we focus on a couple of Recurrent Neural Networks architectures (RNNs), namely Echo State Networks and Long Short-Term Memory Networks, both of which are widely used for several tasks, but not as much for control objectives. In the literature, neural networks are generally investigated empirically, and their properties are obtained by means of a multitude of experiments, rather than by theoretical analysis.

In the thesis, we instead analyse their stability-related system theoretical properties, and derive sufficient conditions for their Incremental Input-to-state stability property; then, we design asymptotically convergent observers and stabilizing model predictive control schemes, eventually tested in simulation.

Finally, Part III deals with a real case study, concerning the cooling station serving a large business center in Milan. A dataset of the plant is available, but a lot of information is missing about the plant, which prevents the derivation of a model through physical equations. A semi-physical model is derived relying also on black-box correlations, and since this model turns to be intractable for control design, a learning-based approach is pursued, a model based on LSTM is learned, and embedded in a MPC control scheme, with linearization along predicted trajectories to lighten the computational burden. The numerical results, tested on the semi-physical model confirm the effectiveness of the learning-based approach.

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