

Title: Smart demand controllers for multi-modal networks

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The energy system is undergoing rapid changes due to the green turn in the energy production and the extensive electrification of the transportation. With the production and consumption changes, new challenges arise and thus new control requirements will be demanded from the network operators, to achieve a safe management. Employing the electric load to control the grid is an attractive solution. Its geographical distribution and the overall energy handled makes it a perfect resource to substitute (or at least support) the conventional generation-based approaches. The control is usually performed via communication, aiming to increase the system controllability for voltage or frequency control purpose. However, in the existing approaches, only the electrical layer of the network is considered, avoiding to address innovative control solutions offered by power electronics. In particular, the Sector Coupling offers the possibility of shifting and storing energy among electrical and other energy layers (e.g., heat, gas) to target grid situations with high penetration of renewables.

The electrical decoupling in Hybrid Networks offers advanced control capability, due to the faster power electronics dynamics. An innovative feature is the possibility to shape the load consumption by means of controlled voltage and frequency variations, acting on the load intrinsic nature to change its consumption under non-nominal voltage and frequency values.

The main objective of this thesis is to develop smart demand controllers that, exploiting the voltage and frequency dependency of the loads and the multi-modal nature of future networks, are able to increase the system controllability. In particular, the focus will be on low- and extra-low inertia grids, that are seen as future electrical system scenario. The thesis will be carried out at the Energy Lab 2.0 facility, where the Real Time System Integration research group takes place. In order to achieve this objective, the following tasks have to be done:

- Analyse and elaborate the load sensitivity of a large set of loads, in particular the ones available in the Energy Lab 2.0 by means of experimental verification. A load sensitivity identification procedure has to be developed and implemented in a power converter, in order to carry out the experimental verifications.
- Develop of a voltage/frequency sensitivity-based controller, that is able to influence the load consumption by means of voltage and frequency variation signals. The controller has to be realized and implemented in a power electronics converter, that will provide the asynchronous decoupling between two networks. The controller will be tested in realistic grid conditions in the Energy Lab 2.0 facility.
- Develop a multi-objective optimization software, that receives the sensitivities from the loads and sets the new optimal voltage and frequency set-points, taking into account the network constraints and loads connection rules. The optimization software has to be integrated in the sensitivity-based controller of the previous task, and tested experimentally.
- Enhance the developed controller and optimization software for controlling frequency and voltage in low- and extra-low inertia networks, in coordination with existing multi-modal energy layers. Considering the complexity of the problem, artificial intelligence and machine learning methods will be considered, in order to achieve an optimal real-time control of the network.