Title: Development and testing of a multi-model hardware in the loop setup

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A key factor in developing and commercializing new technologies is the validation of their performance in realistic network conditions. However, field tests are constrained by the possible impact on system customers, and simulations may not be always accurate. The Power Hardware In the Loop (PHIL) system enables the laboratory testing of new technologies in realistic conditions, coupling the hardware under test with large-scale simulated networks by means of a power amplifier.

Multi-modal systems have shown promising features in improving the energy system controllability. However, on the contrary of the PHIL, that is a well-known testing approach, the validation of multi-modal systems has been proposed only in simulations or in field tests. A power hardware in loop evaluation of multi-modal systems, that involve electrical, heating and gas networks, is currently missing. As example, if such multi-modal hardware in the loop system were available, a micro-combined heat and power (CHP) plant could have been tested connected to simulated electrical, heating and gas network, making the analysis of its performance complete.

The main objective of this thesis is to develop a multi-modal hardware in the loop system, where the power testing is not performed only at electrical level through a power amplifier, but also at heating and gas levels. 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:

- Develop multi-modal power interfaces (e.g., power amplifier for the electrical network and heat pump for the heating network) that can be employed for interfacing the heating and gas layers with the simulated networks, and analyze the possible limitations of each technology (e.g., limitation on the temperature control of thermal loads, lack of bi-directionality of heat exchangers).
- Investigate the multi-modal variables that can be measured, sent to the power interface, and fed back to the simulator, taking into account the available actuators technology. For each of this variable, the limitation of each power interface technology, in controlling such variable, shall be assessed (e.g., assessing the use of pressure instead of temperature has interface variable for the heating interface).
- Develop interface algorithms that can be employed to connect hardware and software sides. The algorithms shall take into account the different system's time constants, and different power interface technologies. As an outcome, an interface algorithm library will be created, that future users can easily plug-and-play in their multi-modal hardware in the loop systems.
- Validate the proposed multi-modal interfaces by means of experimental validation with Energy Lab 2.0 resources (e.g., micro gas turbine, fuel cell, etc.). The accuracy of the experimental validation will be assessed considering natural-coupling hardware behaviors (i.e., the hardware is connected to a real network, without hardware in the loop interface).