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Co-simulation for integrated electrical-thermal systems using MOSAIK framework

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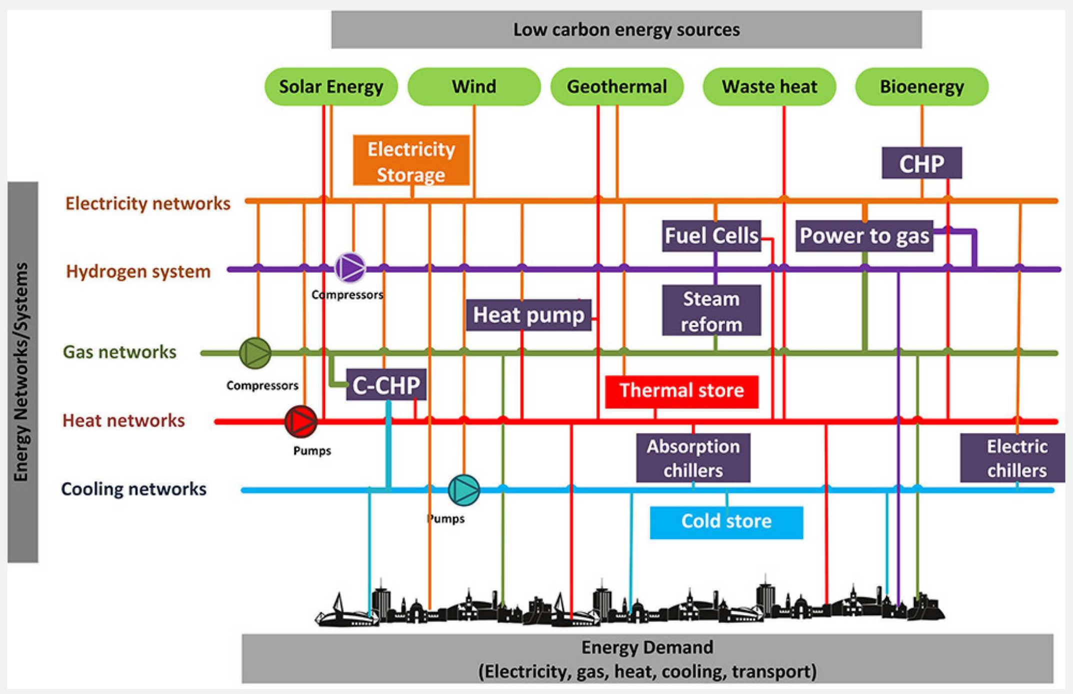
The energy system becomes more and more complex. High penetration of renewables in the electrical grid calls for flexibility to counter balance the stochastic nature of these energy sources. Energy systems integration is a suitable concept to provide such flexibility.

Background

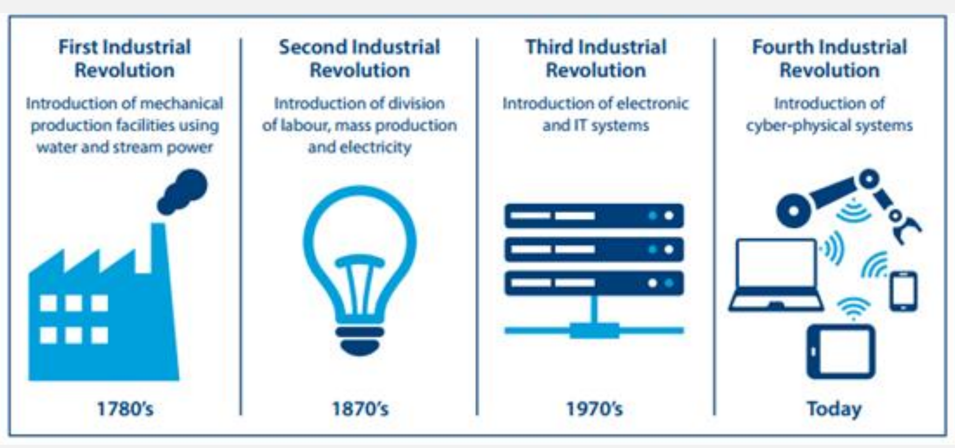
The electrical system is undergoing a massive transition from fossil fuel based generation towards CO2 neutral energy sources such as wind and PV. The latter, in order to contribute to the climate change mitigation measures adopted by most governments . However the electrical system in not the only one evolving and all the others energy sectors (e.g transport, heating) are getting attention in order to achieve a successful energy transition.



Credit: https://peopleandnature.wordpress.com

Energy system integration requires the current *"siloed"* vision of each part of the system, to move towards a holistic view. Each system is becoming a part of an over-heading "master" system grasping and exploiting all aspects of the energy sectors constituting it.

Currently, each sector (I.e electrical, heating, cooling, transport, ..etc.) has a dedicated operation which is centred around its own activities and actors, and uses well its own set of tools for investments planning, market operation, operational analysis and more. As a result of the energy transition and energy systems integration, there is a need for cross-sectoral analysis, simulation and information exchange. The latter being a complex system integrating physical, software, information and communication as well as network aspects.



Credit: https://www.birmingham.ac.uk

The systems being connected together are of different nature (e.g. electricity charge vs hot water for instance), with different dynamics describing them (e.g. electrical voltage vs pressure dynamics in district heating for example) and different operational time scales (e.g below seconds for electricity vs minutes to hours for heating). There is a need for developing tools, capable of analysing the future energy system. As individual sector have well established tools for performing various types of analysis, co-simulation is a suitable alternative to unified language for simulation.

Modeling & Simulation

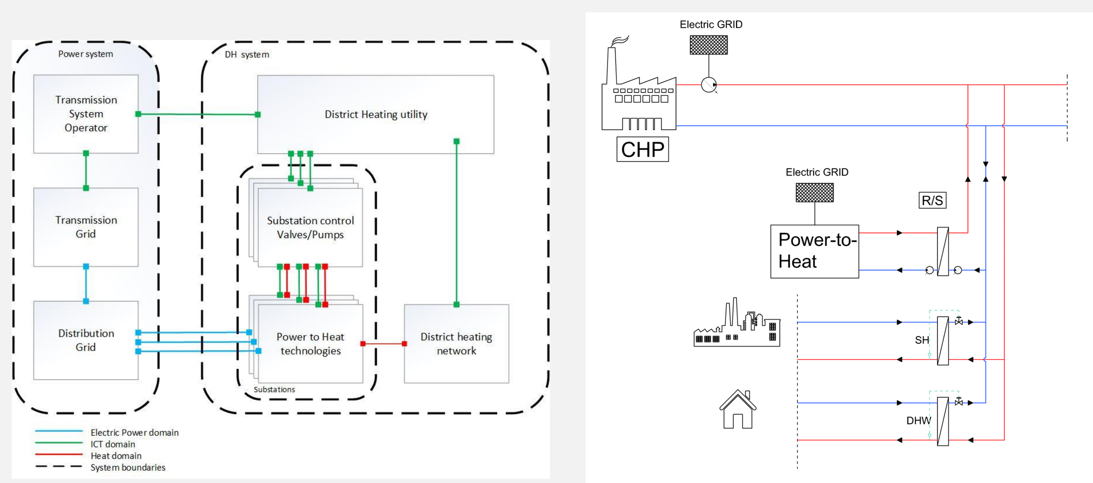
Co-simulation allows to have a holistic simulation platform for coupled systems using a composition of simulators. Each simulator is in charge of a part of the system (e.g. electrical grid, individual component, control entity, network ..etc.). This allows to use well known and well established sector specific tools.

Defining use case is the starting point when simulating a complex system as it allows to identify the relevant actors as well as the different functions to be performed in order for the system to achieve a specific goal.

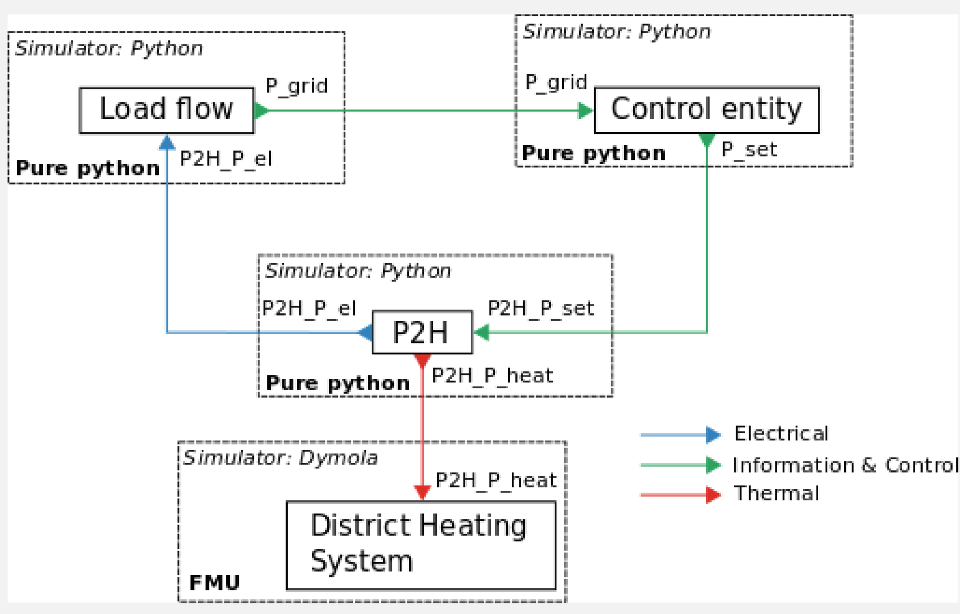
Here we propose to focus on the following use case to demonstrate the capability of performing integrated electrical and thermal systems simulations.

Use Case: Heat production using distributed power-to-heat (P2H) units in the district heating network.

A possible system configuration for such use case could be as follow:



Performing simulation of the afore-introduced system is done using co-simulation with MOSAIK as an orchestrator. MOSAIK allows to combine existing simulation models in order to built large and complex systems. It plays the role of an orchestrator, as it is the central entity collecting necessary information at relevant time and communicating it to the appropriate simulator. The simulation setup used is shown here:

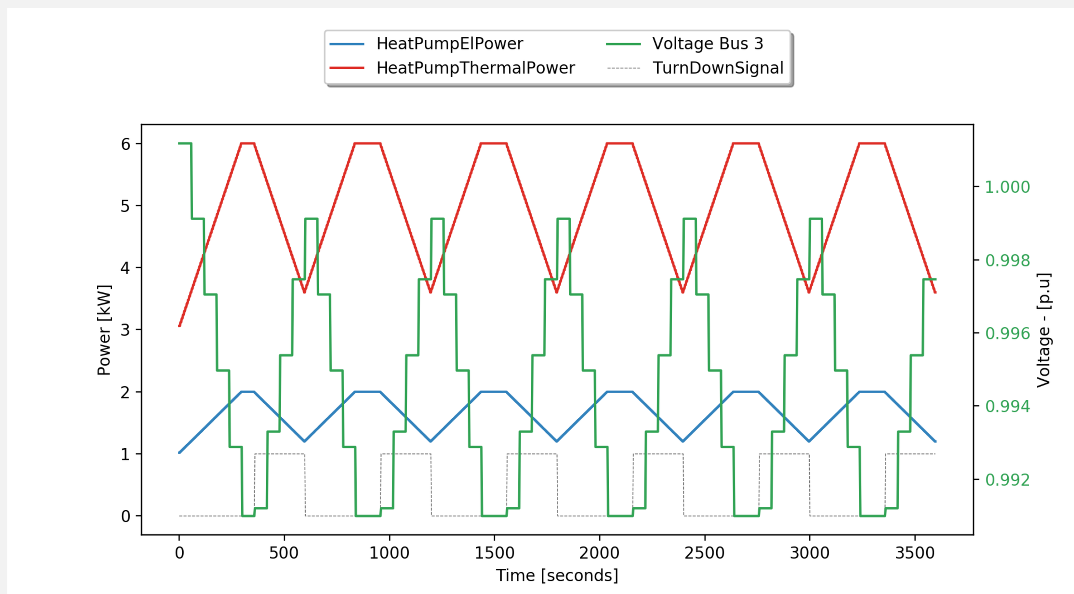


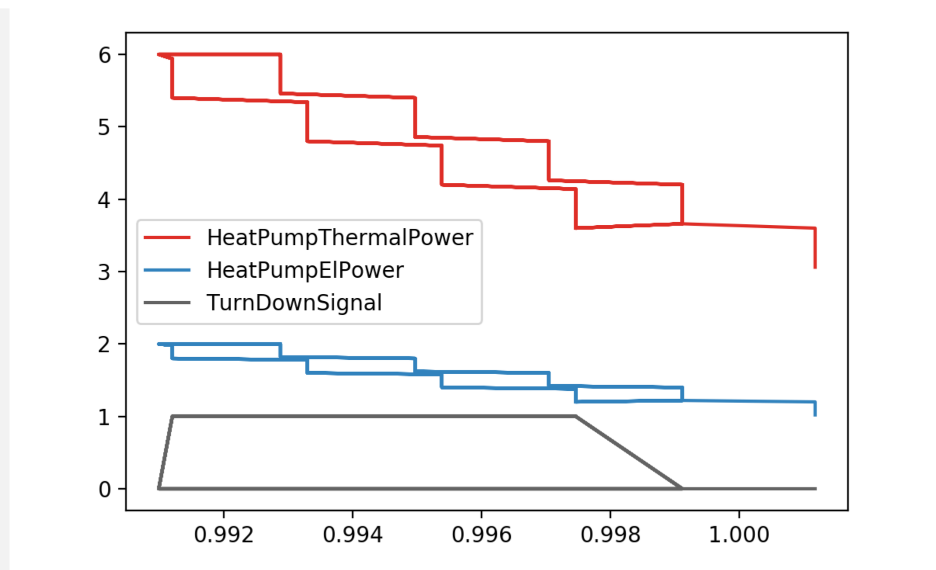
Each of the dashed squares represents a simulation model, independent from the others. The choice for the tool used for each of these is free and can be adapted according to the chosen use case.

Here it is a rather simple setup where a single power-to-heat unit is injecting heat into a district heating network according to the state of the electrical network. There is an intermediate control entity gathering information about the electrical grid state and sending the appropriate set-point to the P2H unit.

Results – Proof of concept

After setting up the appropriate MOSAIK skeleton and building the necessary individual simulators, a simulation can be run.





The first plot shows the dynamics of different variables for different sectors. The heat pump (the P2H) reacts to the "turndown signal" sent by the control entity. That turn down signal is sent, when the voltage at the busbar to which the heat pump is connected on the electrical grid is getting too low. Looking at the second plot, the heat pump electrical consumption and thermal output is plot against the voltage level at the busbar to which it is connected. A the voltage in p.u approaches 1, the heat pump can ramp up again, consuming electricity and producing heat, resulting in a decrease of the voltage. When the voltage level is too low, the turndown signal is sent and the heat pump starts to ramp down

Conclusion:

A simple co-simulation exercise has been shown with a successful implementation using simple models and a limited simulation horizon (1 hours with 1 minute time step). The proof of concept has been established as it was possible to show some cross-simulator dynamics behaviour: voltage disturbance varying together with the heat pump production.

The next steps to be taken are:

- More complex use case
- More actors/simulators
- Apply advanced control strategy
- Increase the number of units deployed
- Automatise part of the building process

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