

Advanced Modeling of Electric Components in Integrated Energy Systems with the TransiEnt Library

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Abstract

In the context of the German Energy Transition, it is planned to increase the share of renewable energies in the next decades in order to decrease the carbon dioxide emissions. Furthermore, the nuclear power phase-out was decided after the Fukushima incident in 2011. In the electrical sector, the renewable energies should have a share of at least 80 % in 2050. The fluctuating generation of the renewable energies must be balanced with the volatile consumption. This is only possible by using storage technology. Electric storages are considered, but their power output and storage capacities are limited and costs per kWh energy storage are high. Hence, the idea of Integrated Energy Systems (IES) to couple the sectors electricity, gas and heat is considered.

For the necessary energy system analysis of IES with respect to dynamics and stability, powerful tools are needed. Such tools should be provided in open toolboxes to make the research more transparent, comprehensive and communicative. It is aimed that scientists collaborate on models for multimodal energy system analysis.

The dynamic simulation is a method that allows to consider transient, non-linear effects and controller design. The TransiEnt Library, developed and established at Hamburg University of Technology (TUHH), offers such a toolbox. Previous versions of the library worked with limited electrical models. The TransiEnt Library is extended with new models. Compared to the limited models, the new electrical models allow much more detailed dynamic modeling and analysis of electric power grids. Load flow calculations can be performed. The stability of the electric grid can be analyzed by considering frequency, voltage and angle stability. This is enabled by new models based on a new connector that allows interconnected networks without overdetermined DAE. Numerically efficient transmission line, transformer and generator models are provided in the TransiEnt Library. Generator models allow different levels of detail in dynamic modeling of the electric grid, starting with simple models that only regard active-power-frequency behavior up to models with excitation systems, Two Axis Method based equations and distinct frequencies. The high modularity of Modelica allows the simple adaption of existing models as well as the extension of existing models.

The main goal is the simulation of a representative coupled system of northern Germany within one simulation model without Co-simulation. Co-simulations typically need interfaces between different partial simulations. These interfaces handicap physical constraints such as mass and energy conservation and reduce the numerical efficiency.

In this complex model, dynamics of the technologies from different energy sectors are coupled in order to cover their interaction. In general, the electric part of the coupled system has higher dynamics than the processes in the gas and heat sector. Consequently, the risk of a stiff problem occurs. To deal with this risk, models are created in different levels of detail for different time scales which can be replaced by each other. Additionally, it is deemed to be reasonable to consider only dynamics with time constants above 1 s in order to avoid stiffness. Furthermore, it is investigated which stability phenomena should be regarded in the electric grid for the chosen time and scenario horizon in order to investigate the overall system resilience.

Keywords: *Integrated Energy System, Electric Energy System, Load Flow Calculation, Frequency Stability, Voltage Stability, Renewable Energy*