Regional electricity system modeling to analyze the impact of storage systems on a renewable energy system

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Overview

With most of the European countries being on track for meeting their renewable energy targets for 2020, the transformation of the European energy system is starting to take shape. Concurrently, with a rising share of renewables, the significance of flexible energy generation and storage is increasing as well. In a future energy system storage systems are indispensable for security of supply from short to long term (Hartmann, 2012; Johansson, 2013). In most scenarios for energy systems with a high share of renewables, energy storage systems are considered essential for the system. The storage technologies in such case are mostly large scale storage applications like PSH and CAES. Due to the falling prices of batteries and PV in the recent years decentralized energy production with combined storage is getting more attention lately (Deutsch, et al., 2015; Consentec, 2013).
In this paper, a regional electricity system modelling is carried out by focusing on the expansion planning and unit-commitment of different kinds of storage systems in the European electricity system. By applying the energy system optimization model ENTIGRIS, the expansion planning of renewables and storage systems is directly linked with the optimization of conventional power plants and transmission grids. The focus within storage technologies is on pumped-storage hydroelectricity (PSH) and compressed air energy storage (CAES) systems for large scale energy storage applications as well as on batteries as decentralized storage systems.

Method

The optimization model ENTIGRIS covers the European electricity system in detail (Kost, et al., 2014). The model connects the existing conventional power plant system, with a high resolution simulation of renewable energy generation. Furthermore an endogenous expansion planning for power plants and transmission lines between European countries are key features within the model. Simultaneously the model optimizes grid extensions between local areas via HVAC lines and HVDC lines between central and southern Europe. The objective function of the model minimizes the annual system costs. ENTIGRIS was extensively used in projects to optimize the German and European energy system as well as in projects within the Middle East and North African (MENA) region (projects are RES-DEGREE, AUTGRID, SUPERGRID). The input and output of the model is displayed in Figure 1: Model input and output of .

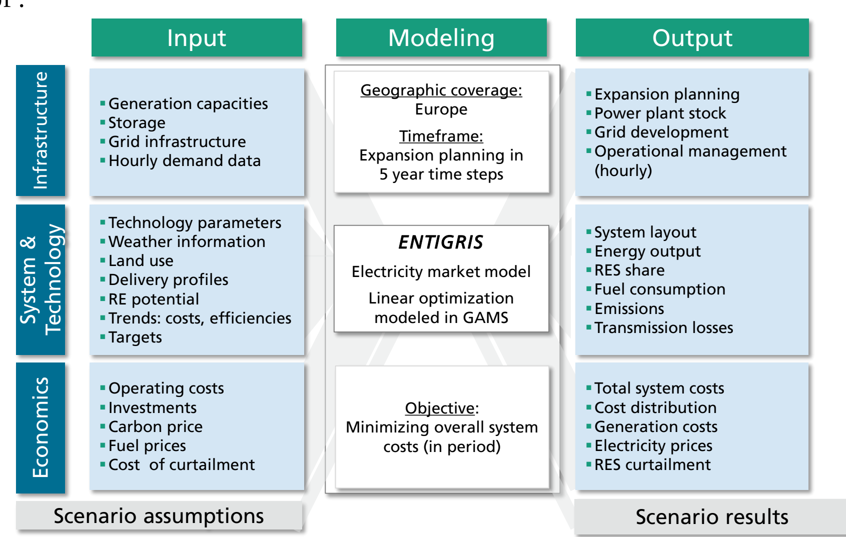

Figure 1: Model input and output of ENTIGRIS

A central aspect of this paper is the revision and improvement of the storage parameters and calculations within the model. The goal is a more accurate reflection of the different types of storages, regarding their potential, costs and operation modes. There are multiple steps to reach that goal. The first step is a literature analysis of existing storage plants and future storage potential for each region. Possible gaps in data have to be closed through an in-depth

analysis. Furthermore an analysis for the cost of the storage technologies and their future development is needed as well. That data allows the integration of the different storage technologies in the model with greater detail.
The map in Figure 2: Regions in the ENTIGRIS Model shows the countries and regions that are part of the model calculations. Germany is divided in 25 regions for electricity demand and production and two additional regions for offshore electricity generation. This detailed regional approach provides the opportunity to analyze regional storage distribution, grid extension vs. storages and impact of suitable RES potential at very specific areas in Germany and at European level.

Figure 2: Regions in the ENTIGRIS Model

Results

The following research topics are addressed in this paper with the new modeling approach applied to storage systems.

- Type and capacity of energy storage, which is needed in the European energy system with a high share of renewables.
- Potential of decentralized battery storage or central storage systems to reduce the expansion of the electricity grid.
- Influence of a decentralized energy generation, storage and consumption on a future electricity grid
- Effect of storage systems on the energy system, which are optimized for a high share of private consumption.

Conclusions

By adapting operation constraints and business models from the current debate into the electricity system model, the outcomes enrich future storage scenarios in the European context. The consequences of strongly decreasing storage costs, use in private households and the European electricity flows (and its constraints between different model regions on a subnational level) will be taken into account.
From the model results it can be concluded that short-term and mid-term business models in the private sector will change the operation of storages and therefore the landscape of storage use in the overall system. In the long-term, grid constraints and benefits from a grid expansion both interact strongly with a potential storage expansion and operation of storage system in an optimized overall electricity system.

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