ELMOD – Transmission Grid load flow model

Overview

The load flow model ELMOD is an optimisation model to analyse interdependencies between electricity generation and transmission with respect to investments and operation. In this regard, both the European transmission grid, conventional as well as renewable generation capacities and electrical demand are represented in a very high geographical resolution (see figure 1). The load flow is approximated by a direct current approach. In its basic framework, the model aims to analyse the impact of renewable energy generation on the transmission grid, dispatch and investment decisions with focus on Europe. In addition, also questions regarding for example market design and congestion management can be examined with ELMOD, as well as the effect of single transmission lines on the electricity system in general. Furthermore, NTC values between separate price zones can be derived.

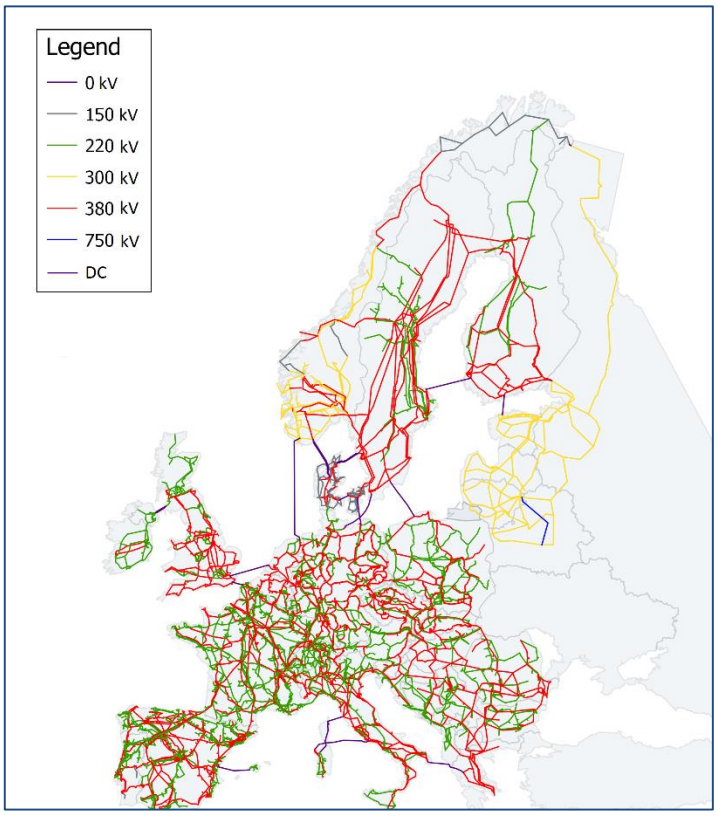

Figure 1: Geographical resolution of ELMOD

Recent model applications

ELMOD has been applied in several projects and studies on national and European level addressing the following topics in the recent years (extract):

- **Grid Modelling:** Modelling the European transmission grid with respect to nodal pricing systems, grid connection of East-European energy supply infrastructure and market power at different market designs (Leuthold et al. 2010, ESA[2])
- **Congestion Management:** Research on market design focusing on Congestion management and utilization of transmission lines (Kunz 2013, Energiewende Sachsen (ongoing))
- **Wind Energy:** Feasibility studies on grid connection and integration of offshore wind energy generation (Weigt et al. 2010)
- **Transmission Grid Expansion Planning:** Method orientated research on (cost-) optimal extension of the European transmission grid (ongoing)

Database

Within the above mentioned studies, but also incorporating the results from project work in the recent years, the database has been improved continuously. It builds mainly on public available data (e.g. public entities, public/industrial agencies):

Power plant portfolio: European Network of Transmission System Operators for Electricity (entso-e), country specific data from public entities (e.g. ministries or agencies)

Grid infrastructure: European Network of Transmission System Operators for Electricity (entso-e)

Time series for renewable feed-in: Publicly available time series of wind speed, solar radiation and water flows (country specific)

Electricity demand: European Network of Transmission System Operators for Electricity (entso-e, EUROSTAT)

Commodity prices: EUROSTAT, country specific data from public entities (e.g. ministries and agencies)

Model structure

ELMOD has got a bottom-up approach with welfare maximisation as objective function respectively minimisation of total system costs. Essential constraints are physical characteristics of load flow, energy balance and generation restrictions. The implemented generation technologies cover beside conventional and renewable power plants also storage plants, such as e.g. pump water storage (all technologies are plant specific). Generation

technologies, the transmission capacities and electrical demand are represented geographically referenced. This allows in particular the coupling with further research works concerning renewable energy potentials, carried out at the Chair of Energy Economics. Due to the high degree of technical accuracy, single time slices on hourly basis covering different scenarios are implemented.

Modeling investment decisions

Investment decisions are modeled endogenously. Based on annuity of investment costs and variable operation and maintenance costs, the model determines the cost optimal transmission line upgrade.

Modeling policies

ELMOD considers all present policies concerning the European electricity market:

Feed-in priority of renewable energies is implemented in each country with the respective regulatory framework.

EU emission trading is modelled implicitly with the help of prices for CO_2 allowances. According to the emission factor these prices influence the generation costs for all fossil power plants.

The *Ten-Year Network Development Plan and Regional Investment Plants* for grid infrastructure are considered according to entso-e.

Selected references

Kunz, Friedrich: Improving Congestion Management: How to Facilitate the Integration of Renewable Generation in Germany. The Energy Journal, Vol. 34, No. 4. IAEE 2013.

Leuthold, Florian; Weigt, Hannes; Hirschhausen, Christian: A Large-Scale Spatial Optimization Model of the European Electricity Market, Journal of Network and Spatial Economics, 2010.

Weigt, Hannes; Jeske, Till; Leuthold, Florian; von Hirschhausen, Christian: Take the long way down - Integration of large-scale North Sea wind using HVDC transmission, Energy Policy, Vol. 38, Issue 7, July 2010, Pages 3164-3173.