SwissMod – A model of the Swiss electricity market

Ingmar Schlecht and Hannes Weigt

Forschungsstelle Nachhaltige Energie- und Wasserversorgung (FoNEW)
WWZ, University of Basel
Peter Merian-Weg 6
Postfach, CH-4002 Basel
Mail: ingmar.schlecht@unibas.ch, hannes.weigt@unibas.ch

(1) Overview

The energy landscape in Switzerland is facing major changes in the near future. A departure from nuclear energy, having provided about 40% of electricity production in Switzerland so far, along with a shift towards new renewable energy sources marks a significant shift of energy policy. The Swiss Federal Office of Energy has launched the so called 'Energy Strategy 2050' (BFE, 2012) providing a first estimation how the replacement of nuclear plants and a transition towards a sustainable and renewable energy system can be achieved. As the electricity system plays a crucial role in this development an adequate representation of the specific nature of Switzerland's electricity market will be needed to identify potential challenges in the transformation process and potential bottlenecks in the electricity supply and transmission system.

Given the mountain-rich geography of Switzerland, the most important domestic source of electricity is hydropower, making up for slightly more than 55 % of total supply, while fossil powered plants and new renewables together account for less than 5%. In any model of the Swiss electricity market, detailed modeling of hydroelectricity therefore is crucial to obtain reasonable results. As no existing economic model so far accounts for those aspects, the objective of our paper is to develop a model of the Swiss electricity market using the DC load flow approach coupled with a detailed representation of the underlying hydrological system of interlinked lakes and rivers. Besides a detailed representation of the transmission grid and international interconnections, we therefore put special emphasize and a high degree of detail on the modeling of hydroelectricity and the overall hydraulic system of Switzerland in order to capture the most important electricity source in the country adequately.

(2) Methods

Our approach is based on the DC load flow approach following Schweppe et al. (1988) and Leuthold et al. (2012) to model an electricity transmission system with a nodal pricing approach. SwissMod covers the whole transmission system of Switzerland as well as its interconnections to neighboring countries (Fig. 1). Generation and demand is allocated on a nodal basis to allow an estimation of congestion aspects. The model is designed as linear cost minimization approach, coded in GAMS and solved using the CPLEX solver.

Due to the importance of hydroelectricity in Switzerland, special focus is put on its detailed modeling. The model captures all forms of hydroelectricity, run-of-the-river, storage and pumped-storage power plants. Using a separate network, the hydraulic system of Switzerland is modeled based on a dataset by the Swiss Federal Office of Topography (SwissTopo) containing all rivers and lakes in the country. Using this network, water flows on the network are endogenously determined, so that the outflow of an upstream hydro power plant results in an inflow to a downstream power plant with a defined time lag. By means of the modeling of storage possibilities in storage lakes (upper basin, lower basin), the available water resources are used efficiently by the system. The modeling of the hydraulic system as a fully separate network enables the "plugging-in" of hydro power plants into any point in the water network, automatically placing it in the correct order of a hydro cascade.

(3) Scenarios

We conduct a scenario analysis to show the potential consequences of energy policy in Switzerland based on the 'Energy Strategy 2050' (BFE, 2012) estimates. In a first scenario the current system and observed generation and transmission patterns are reproduced to calibrate SwissMod and provide a benchmark for the different extension scenarios. In a second scenario we model the consequences of phasing out nuclear power without implementing counter-measures. Consequently, this will lead to an increase of imports to compensate the 40% generation reduction, subsequent changes in export patterns towards Italy and resulting feedback effects within the central European electricity markets.

In a third scenario we will analyze the replacement of the nuclear plants by an increased RES share. The resulting flow pattern and plant dispatch will depend on the underlying assumptions regarding the spatial distribution of the added intermittent RES capacities. This will also lead to changes in the usage of (pumped-) storage hydropower plants. Although hydropower is often cited as a crucial element of a transition towards a largely RES driven electricity system the hydrological restrictions may lead to additional limitation as cascading hydro plants depend on their

predecessor and impact their successors thereby leading to time lagged system wide impacts of local RES injection. The detailed representation of the hydrologic topology of Switzerland within SwissMod will provide first insights into this aspect of electricity markets.

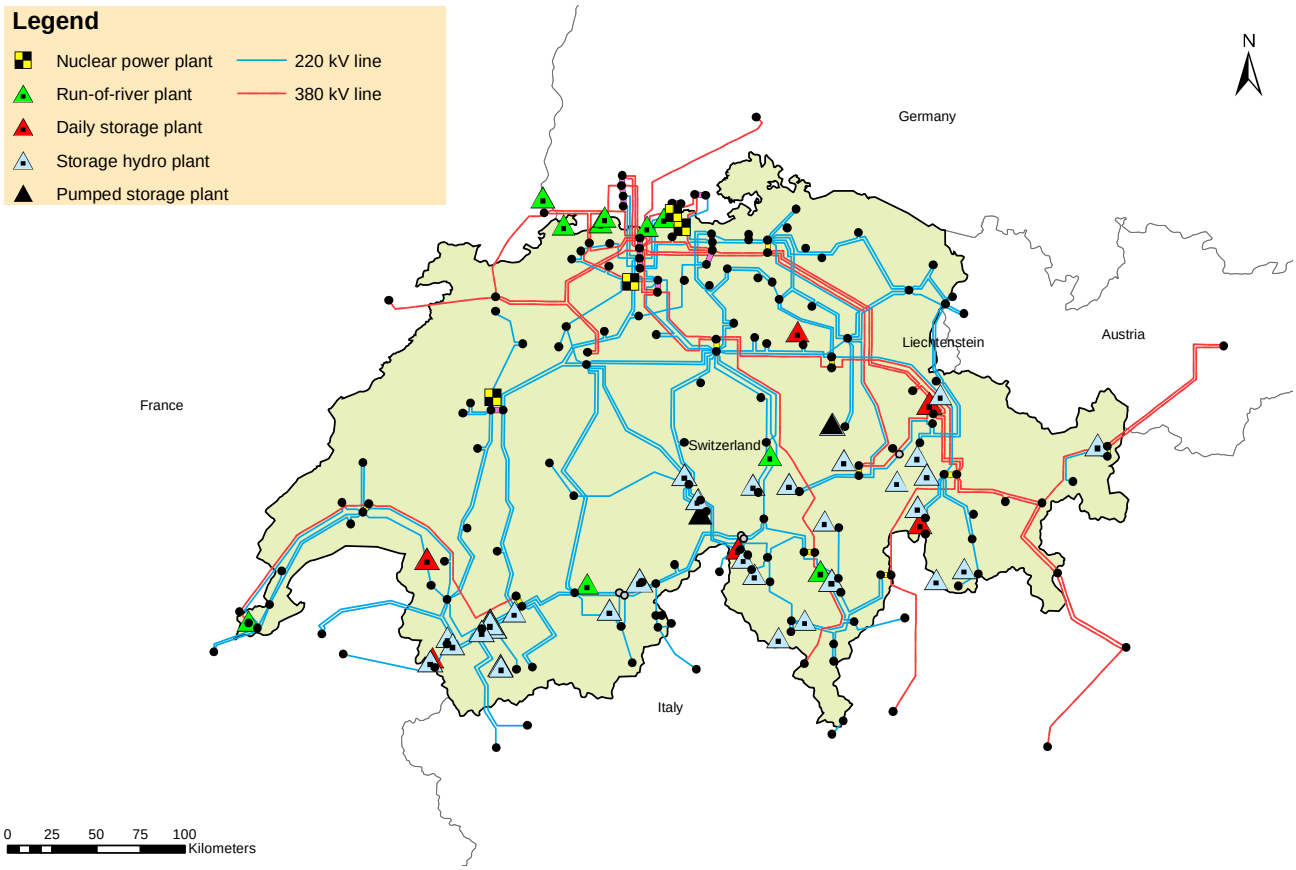

Fig. 1: The spatial GIS database of SwissMod holds the model parameters

(4) Conclusions

SwissMod captures the building blocks of the Swiss electricity market covering both the basic electricity characteristics and hydrological fundaments. This allows us to model the impact of future energy policies, capture the reactions of the different system components and provide estimates for the impact on the Central European electricity markets. Especially the hydropower system of Switzerland has a large potential to adapt to changing patterns of power production and can play a major role in stabilizing the European electricity system when high shares of intermitted RES generation are commonplace. The degree of detail in our model makes it possible to analyze how the usage patterns of hydropower is changing with different market conditions and their impact on overall market outcomes both in a spatial and time dimension. Therefore, combining a DC electricity load-flow model with a model of the hydraulic system yields important conclusions for Switzerland and its neighboring countries and can be applied similarly to other countries with a large share of hydropower.

References

BFE Swiss Federal Office of Energy (2012) “Erläuternder Bericht zur Energiestrategie 2050”, available online at http://www.bfe.admin.ch/themen/00526/00527/index.html?lang=de&dossier_id=05773 (last accessed: 15 March 2013)

Leuthold, Florian U.; Weigt, Hannes; Hirschhausen, Christian von (2012) “A large scale spatial optimization model of the European electricity market”, *Networks and spatial economics* 12 (1), 75–107.

Schweppe F., Caramanis M., Tabors R., Bohn R. (1988) “Spot Pricing of Electricity”, Kluwer Academic Publishing, Norwell, MA.