System Adequacy in Hydro Rich Countries: Proposing an Energy Aware Indicator

Ingmar Schlecht, University of Basel, +41 61 207 33 45, ingmar.schlecht@unibas.ch
Jonas Savelsberg, University of Basel, +41 61 207 55 28, jonas.savelsberg@unibas.ch
Moritz Schillinger, University of Basel, +41 61 207 28 72, moritz.schillinger@unibas.ch
Hannes Weigt, University of Basel, +41 61 207 32 59, hannes.weigt@unibas.ch

Overview

System adequacy is important in order to maintain a desired level of supply security and assure that generation as well as network capacity are sufficient to cope with peaks in residual load.

System adequacy indicators so far have focused on measures that mainly compare available generation capacity to expected load to calculate the probability, frequency or severity of potential losses of load to be expected (JRC, 2016). However, for hydro rich countries there is another important determinant of system adequacy, namely the amount of water stored in reservoirs for electricity production from storage hydro facilities. Measures existing today have neglected that feature due to their singular focus on generation capacity. However, effectively a lack of stored energy in storage lakes can reduce the generation capacity actually at disposal of market actors and system operators.

We therefore propose a new indicator of system adequacy that focuses on the number of hours a hydro rich electricity system is able to cover its load without imports from neighbouring countries, i.e. in a hypothetical autarky. Considering a hypothetical autarky is important because in critical system situations a regulator carrying out such system adequacy analyses can only reliably count on the generation capacity that is under its jurisdiction. The indicator we propose is called Storage Autarky Possibility Hours (StAP) and is detailed below.

The analysis in out paper is twofold. In the first part, we first present the literature on existing system adequacy indicators and their usage by European regulators and supranational organisations before introducing our own indicator that takes hydropower storage contents and its impact for system adequacy into account. In the second part, we present an exemplary application of the newly developed indicator to the Swiss electricity system. That analysis is based on a nodal pricing DC load-flow electricity dispatch model for Switzerland called Swissmod (Schlecht and Weigt, 2014). Finally, the last section concludes.

Methods

The first part, namely the derivation of the gap in the literature and the development of the StAP indicator filling the gap in terms of hydropower storage considerations for system adequacy, is based on a literature review that takes into account both academic papers as well as important system adequacy reports by key industry players such as ENTSO-E, ACER and selected national regulatory agencies carrying out system adequacy studies in hydro-rich countries.

The second part, namely the model-based exemplary calculation of the StAP indicator we propose, is based on Swissmod, a DC load-flow nodal pricing electricity market model for Switzerland. The model framework has been tailored to allow for an in depth analysis of possible future market designs in Switzerland. As a first step, a yearly nodal pricing model of the Swiss electricity market based on the DC load flow approach (see e.g. Leuthold et al. 2012 or Schlecht and Weigt 2014) has been set up. This model incorporates a detailed representation of the Swiss power system and aggregated surrounding regions with a focus on hydropower elements on the one hand and a representation of balancing markets on the other. As a defining feature of Swissmod, hydro power stations in the model are represented in a high degree of detail, modelling their hydrologic interrelation within hydropower cascades, so that the outflow of an upstream power plant ends up as inflow to a downstream power plant. Line flows are represented using a DC load flow approach so that the marginal or dual variable on the energy balance can be interpreted as the hourly locational marginal electricity price.

To obtain results for the newly developed StAP indicator, we first derive the hourly market results for different potential market scenarios (i.e. dry/wet year, hot/cold year, etc.). As an ex-post assessment we then derive the energy content of stored water in storage lakes in Switzerland for each given hour of the modelled year. In a second step, we calculate the cumulative residual load of subsequent model hours and calculate the point at which the cumulative residual load exceeds total water stored in storages lakes to obtain the StAP value. The hourly indicator will provide an estimate how close the system is to critical supply conditions. Therefore, StAP represents a more dynamic evaluation than the existing static indicators and allows combining market dynamics, hydro storage characteristics and renewable generation structures into a comprehensive metric.

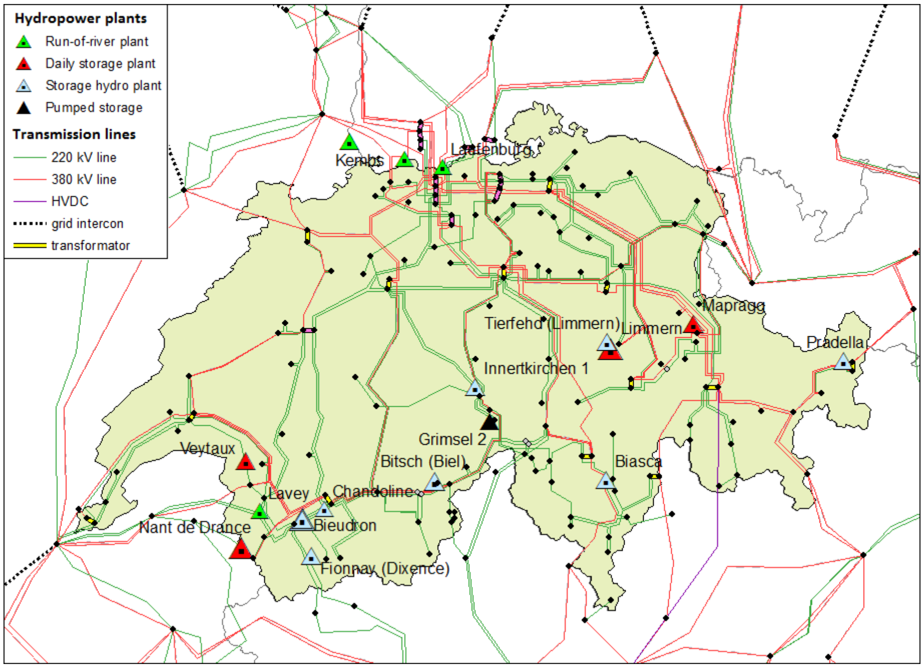

Figure 1: Underlying Swissmod GIS database with power lines and hydropower stations

Results

We are in an advanced modelling stage so far but cannot present final results to date. They are expected to be finalized mid to end of April 2017 and will therefore be included in the paper draft to be submitted to the IAEE Vienna conference.

Conclusions

The system adequacy indicators used in analyses so far have focused statically on the generation capacity existing in a given country. Thereby, the indicators disregard an important dynamic feature of system adequacy, namely the fact that generation capacity is endogenous to the usage of storage hydro over the year. If storage water is used up early, this effectively reduces generation capacity for later hours in the year and thereby impacts system adequacy. To capture this effect, it is necessary to complement existing indicators with one that focuses on the energy stored in storages lakes and compares this to residual load. The indicator we propose fills this critical gap for hydro rich countries and shows in an exemplary application to Switzerland which time periods and scenarios are the most critical in terms of actual supply security.

References

JRC (2016). Generation Adequacy Methodologies Review. Joint Research Center of the European Commission. Report EUR 27944 EN.

Leuthold, F. U., Weigt, H., & Von Hirschhausen, C. (2012). A large-scale spatial optimization model of the european electricity market. *Networks and spatial economics*, *12*(1), 75-107.

Schlecht, I., & Weigt, H. (2014). Linking Europe-The Role of the Swiss Electricity Transmission Grid until 2050.