Electricity Market Integration in North America: A Quantitative Analysis for Transmission and Generation Planning

Elmar Zozmann, Workgroup for Infrastructure Policy / TU Berlin, ez@wip.tu-berlin.de
Citlali Rodriguez del Angel, Workgroup for Infrastructure Policy / TU Berlin, cra@wip.tu-berlin.de
Theo Schönfisch, TU Berlin, teo.s@gmx.de
Andrea Ruíz López, TU Berlin, andrea.r.ruizlopez@campus.tu-berlin.de

Overview

Within the framework of the Paris Climate Agreement and the submission of the Nationally Determined Contributions, the United States, Mexico and Canada have set themselves ambitious targets regarding greenhouse gas emission reduction. In addition, Mexico, many U.S.-states and some Canadian states have specific renewable targets. In the upcoming decades, the integration of high shares of intermittent renewable electricity will thus be one of the major tasks for the future North American energy system. Although some cross-border cooperation has been going on, there is still a high potential of intra-regional cooperation. Among other flexibility options, increased international electricity market integration in combination with cross-border capacity expansion can contribute to the process of integrating high renewable shares.

The U.S. and the Canadian electric power grids are already highly interconnected, providing benefits to both states like enhanced electric reliability, security, affordability and resilience as well as increased economic benefits. The comparatively clean electricity production in Canada could assist the United States in meeting their clean energy goals and provide pumped-reservoir storage capability for excess quantities of fluctuating renewable power. This matter has already been investigated by Beiter et al. (2017), Ibanez and Zinaman (2016) and Elizondo et al. (2017).

However, electricity trade across the U.S.-Mexican border is significantly less and the grid lacks the necessary infrastructure. Similar to the clean electricity production in Canada, there is a large potential for the deployment of photovoltaic generation in Mexico. Hence, this paper investigates the benefits of an increased overall cross-border transmission capacity, taking into account not only the U.S. and Canada but also the Mexican electricity system.

Methods

We use a cost-minimizing economic dispatch model to quantify the benefits of an increased cross-border trade of electricity. The model structure corresponds to a DC load-flow representation in line with the ELMOD-model (Leuthold, et al., 2012). We put particular emphasis on the variability of renewables, as well as the structure of demand. Some demand-side flexibility (DSM) options are available, too.

The continent is divided in eight different market zones in line with the North American Interconnections (see Figure 1). For each zone, regionally differentiated input data is considered, such as installed generation and storage capacity, marginal costs of electricity generation, fluctuations in renewable production as well as electricity demand. Cross-border electricity trade is restricted by the Net Transfer Capacities (NTCs) according to the existing cross-border transmission capacity. Zonal markets are cleared in an hourly resolution for one year.

To this end, we compute four scenarios differing in the amount of cross-border transmission capacities and shares of renewable energy. The effects of an expansion of cross-border capacity are examined under the current and an increased future share of renewable generation capacity. Results are then compared with a scenario reflecting the status quo as well as with a scenario with renewable capacity expansion but without grid expansion.The comparison of these four scenarios gives insights into how beneficial the market integration of the North American System is with respect to the ambitious renewable targets.

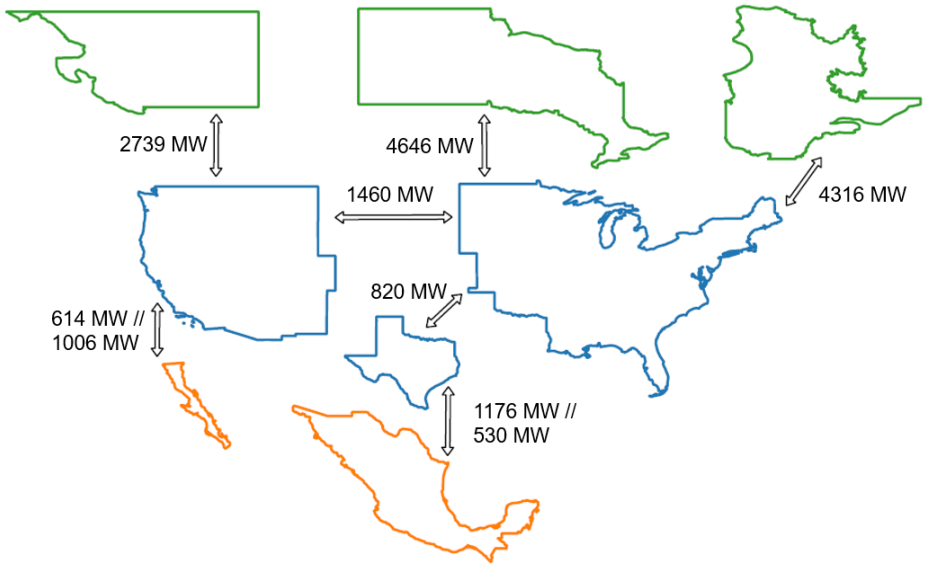

Figure 1: Zonal splitting and NTCs based on existing cross-border capacities.
Source: Own representation based on U.S. Energy Mapping System, 2018

Preliminary results and conclusions

The model has been set up and first trial runs have started, we expect results until May 2019. From first model runs, some tendencies emerge already, though: Scenarios based on increased cross-border transmission capacities depict a reduction in total system costs as well as an increased overall renewable production, even under today's comparatively low share of renewable energies in the United States. This effect could be further increased in future scenarios with higher shares of renewable energies. The results additionally show that the currently existing cross-border transmission capacity between Texas and Mexico as well as between Quebec and eastern U.S. is constantly fully utilized. Policy implications could thus include recommendations for a region-specific expansion of cross-border transmission capacity. With respect to high shares of renewable energies, the North American market integration comprising the United States, Canada and Mexico could hence provide a first piece of needed system flexibility.

References

Beiter, Philipp, Wesley J. Cole, and Daniel C. Steinberg (2017). "Modeling the Value of Integrated U.S. and Canadian Power Sector Expansion." *The Electricity Journal* 30 (2): 47–59.

Elizondo, M. A., N. Mohan, J. O'Brien, Q. Huang, D. Orser, W. Hess, H. Brown, et al. (2017). "HVDC Macrogrid Modeling for Power-Flow and Transient Stability Studies in North American Continental-Level Interconnections." *CSEE Journal of Power and Energy Systems* 3 (4): 390–398.

Ibanez, Eduardo, and Owen Zinaman (2016). "Modeling the Integrated Expansion of the Canadian and US Power Sectors." *The Electricity Journal* 29 (1): 71–80.

Florian Leuthold and Hannes Weigt (2012): A Large-Scale Spatial Optimization Model of the European Electricity Market. Networks and Spatial Economics .