ANALYSING ZONAL PRICES FOR THE AUSTRIAN POWER SYSTEM

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Motivation

Electricity trading in Europe works with so called bidding zones, where (in most cases) one bidding zone equals to one country. Within such bidding zones electricity can be traded without any restrictions as it is assumed that there are no congestions within a zone. Therefore, there is only one resulting price for each bidding zone. The amount of electricity that can be traded between different bidding zones is limited by cross-zones interconnection capacities. As long as the limit of the cross-zones capacities is not reached the price between zones is the same. If trading between zones exceeds the cross-border capacities, prices will begin to diverge with cheaper prices in the zone that wants to export and higher prices in the zone that wants to import electricity. This price determining approach is called zonal pricing. [1]

For this paper the open-source low-carbon electricity generation (LEGO) model is expanded to calculate zonal prices. This allows the comparison between two different pricing systems: (i) nodal pricing, where every node has its own price and (ii) zonal pricing where each zone is represented as a single node, which means, that there are no congestions within a zone.

In the full paper the mathematical implementation of zonal prices into the LEGO model is described. The updated model is then utilized to analyse the difference between nodal pricing and zonal pricing for a power plant investment decision using the Austrian electricity system.

LEGO – Low-carbon Electricity Generation Optimization model

LEGO is an open-source model, freely available on GitHub[2], which is a mixed-integer quadratically constrained expansion planning program. It is designed to be very flexible. For example, it can either run with chronological hourly data or with representative periods. It also has different option blocks that can be switched on or off depending on the analysis like running the simulation with or without (single node) network constraints, DC- or simplified (via second order programming) AC-optimal power flow, whether to consider demand side management or not and more.

For a better understanding of the LEGO model the reader is referred to [2] where the mathematical formulation with its objective function and constraints is already explained in detail.

Currently electricity prices are calculated per node (nodal pricing), which is not the method used in Europe where, electricity prices are calculated on a per bidding zone basis (zonal pricing). To calculate those zonal prices as well, the LEGO model is adopted and expanded:

1) Introducing a new set z for the different zones
2) Assigning each node i to its zone z in a new set $iz(i,z)$
3) Generating dynamic sets to assign generators to zones $gz(g,z)$ and to identify lines between different zones $lbz(i,j,c)$
4) New balance constraint for zones (with its dual variable representing the zonal price)

This new concept of zones is pictured in Figure 1, where each country is represented by its own zone ($z(AT)$, $z(DE)$, …). The generators are assigned to their corresponding zone in the dynamic set $gz(g,z)$ based on the set $iz(i,z)$ which defines the relationship between node i and zone z. To identify the transfer capacities between zones, a second dynamic set $lbz(i,j,c)$ is generated which only contains lines which connect different zones.

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[2] https://github.com/wogrin/LEGO

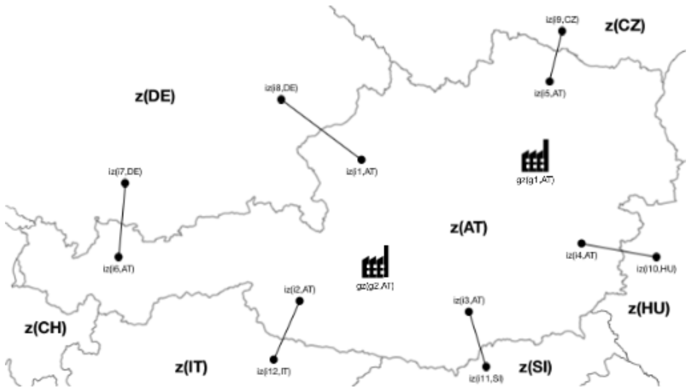

Figure 1:Concept of zones where each country is its own zone z. The dynamic set $gz(g,z)$ represents the generators within a zone and the dynamic set $lbz(i,j,c)$ contains all lines between different zones.

Furthermore, a new constraint for zones is introduced to account for the balance within a zone. It sets the equilibrium between the demand from the zone and the generation, flow to and from the zones as well as export and import[3]. The mathematical formulation of the constraint will be explained in the full paper.

Preliminary Results

The first results of zonal prices in LEGO for Austria with seven representative days can be seen in Figure 2. The prices range between 0 €/MWh (hours where the whole demand can be covered with renewables) and 139 €/MWh. The model is currently running with pumping turned off for pumped-storage power plants, as those would flatten the price curve because of perfect information for the optimizer.

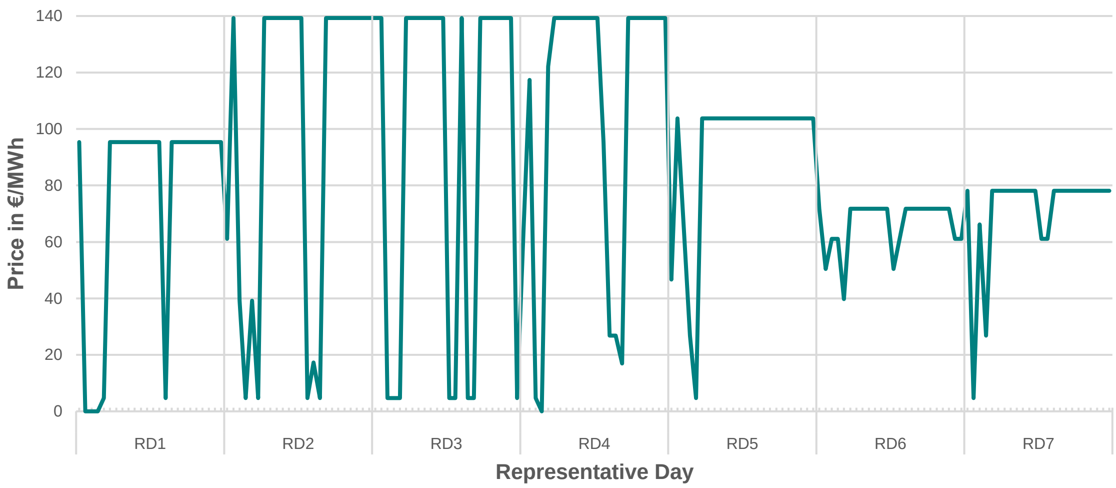

Figure 2: Hourly zonal prices for seven representative days for Austria 2020

References

[1] P. F. Borowski, "Zonal and Nodal Models of Energy Market in European Union", doi: 10.3390/en13164182.
[2] S. Wogrin, D. Tejada-Arango, S. Delikaraoglou, and A. Botterud, "Assessing the impact of inertia and reactive power constraints in generation expansion planning," *Applied Energy*, vol. 280, p. 115925, Dec. 2020, doi: 10.1016/J.APENERGY.2020.115925.

[3] Import and Export are parameters used to emulate one-country-simulations. Import is defined as the electricity imported to a zone and export is defined as the electricity exported from a zone without its own generators. Both parameters are only defined for zones which are not modelled in detail.