Hierarchical Balancing in Zonal Markets

Anthony Papavasiliou, UCLouvain

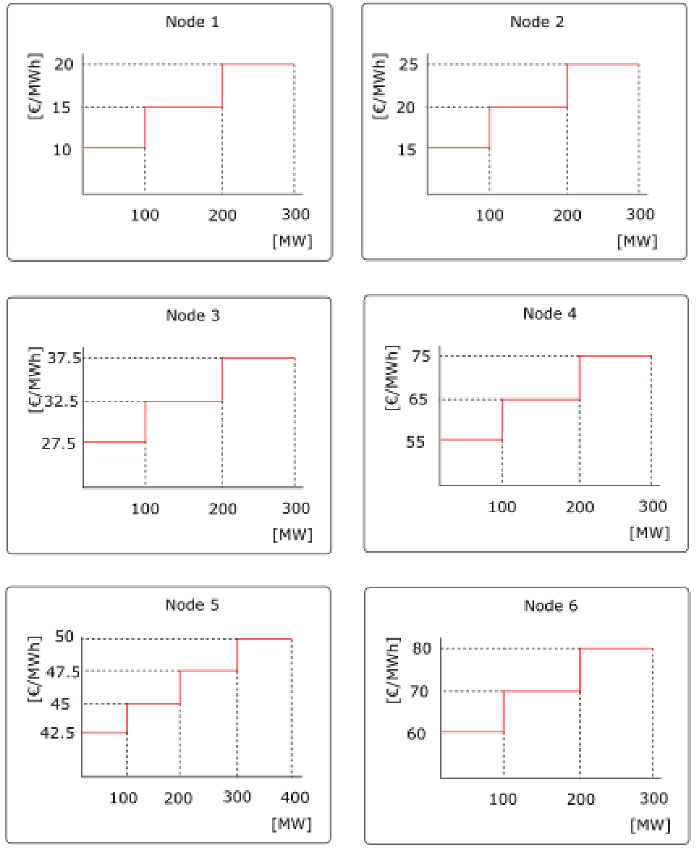
Joint work with M. Bjorndal (NHH), G. Doorman (Statnett), N. Stevens (N-SIDE)

17th International Conference on the European Energy Market

Motivation

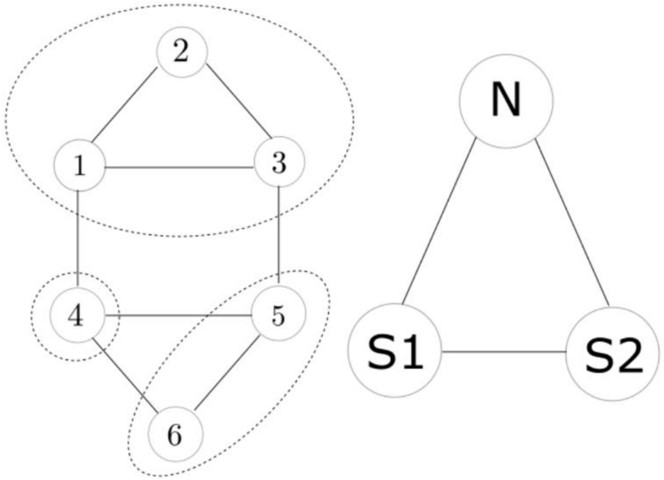
- In MARI, which will be going live in the following years [1] (see also article 20.6 of [8]), the network is approximated using an ATC transportation-based model
- Numerous problems related to zonal market clearing
    1. Operational inefficiencies [1]
    2. Gaming opportunities [2]
    3. Distortion of long-term investment signals [3]
    4. **Difficulties in maintaining operational security – this paper**
- We propose a hierarchical approach for incorporating nodal network constraints to a zonal market clearing model
- Full study published by Statnett [4]

Illustrative Scenario



Line	Limit (MW)	Susceptance	PTDF 1	2	3	4	5	6
1-2	125	1	0.088	-0.530	-0.105	0.030	-0.020	0
1-3	180	1.5	0.279	-0.011	-0.332	0.094	-0.064	0
1-4	300	1.6	0.634	0.540	0.437	-0.124	0.084	0
2-3	170	0.9	0.088	0.470	-0.105	0.030	-0.020	0
3-5	200	1.1	0.366	0.460	0.563	0.124	-0.084	0
4-5	125	1.3	0.160	0.095	0.023	0.329	-0.223	0
4-6	125	0.95	0.474	0.446	0.414	0.547	0.307	0
5-6	270	1.4	0.526	0.554	0.586	0.453	0.693	0

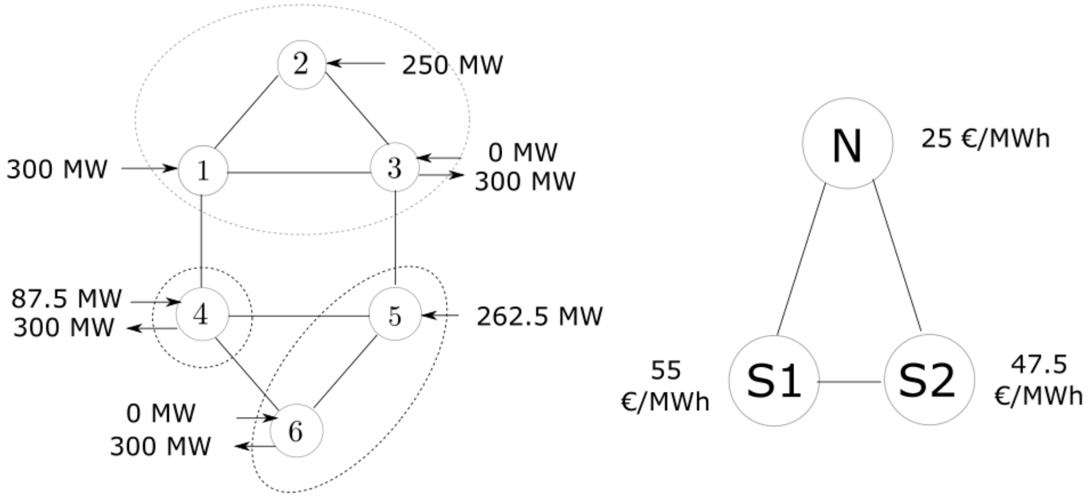
DA zonal model



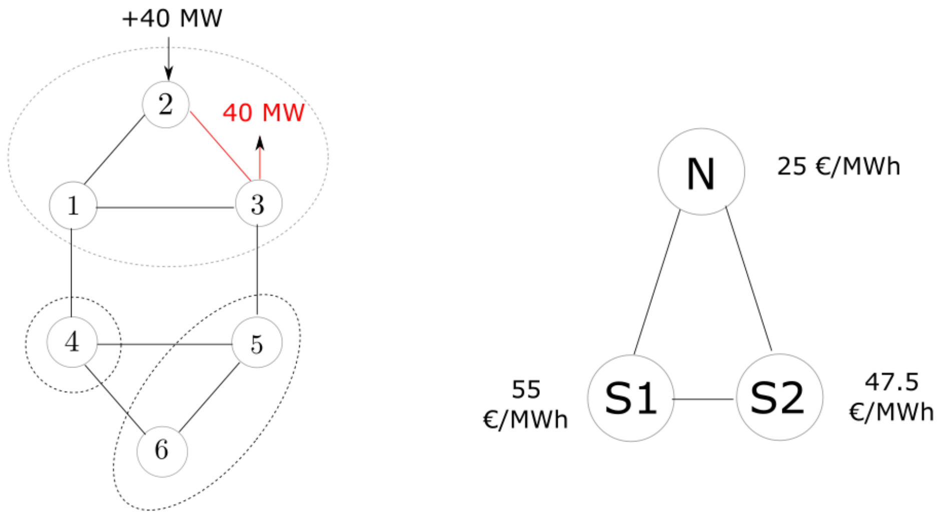
- Six nodes
- Price-inelastic demand in nodes 3, 4, and 6 (300 MW each)
- Six-node network is partitioned into a North zone with cheap generation and two South zones with more expensive generation
- ATC limits for zonal model:
  - 150 MW for link N-S1
  - 100 MW for link N-S2
  - 62.5 MW for link S1-S2.

Illustration of the Problem

In real time, and imbalance of -40 MW occurs in the Northern zone (node 3)



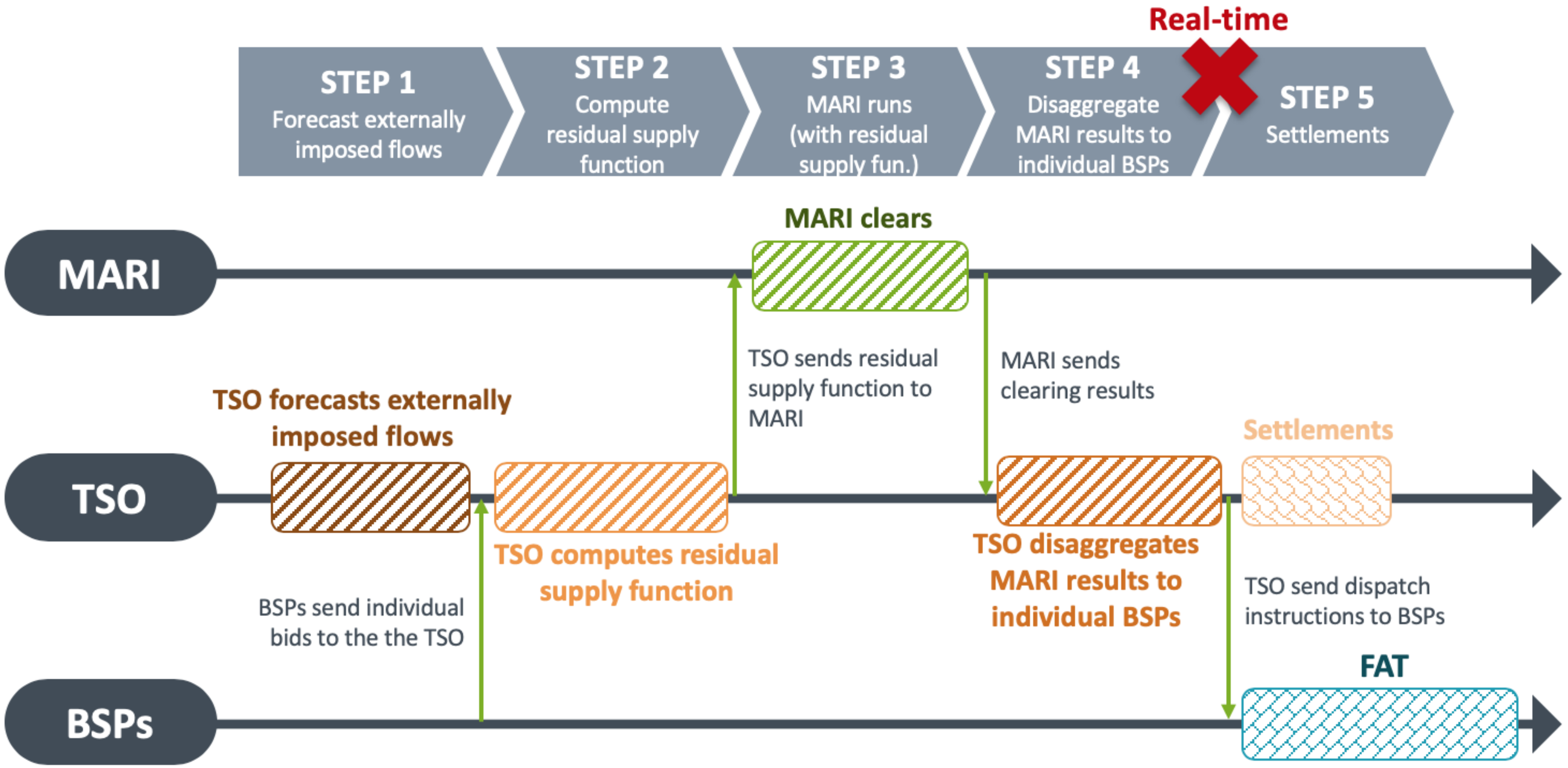
DA zonal market clearing



RT zonal market clearing

RT zonal market clearing violates thermal limit of line 2-3

Proposed Solution

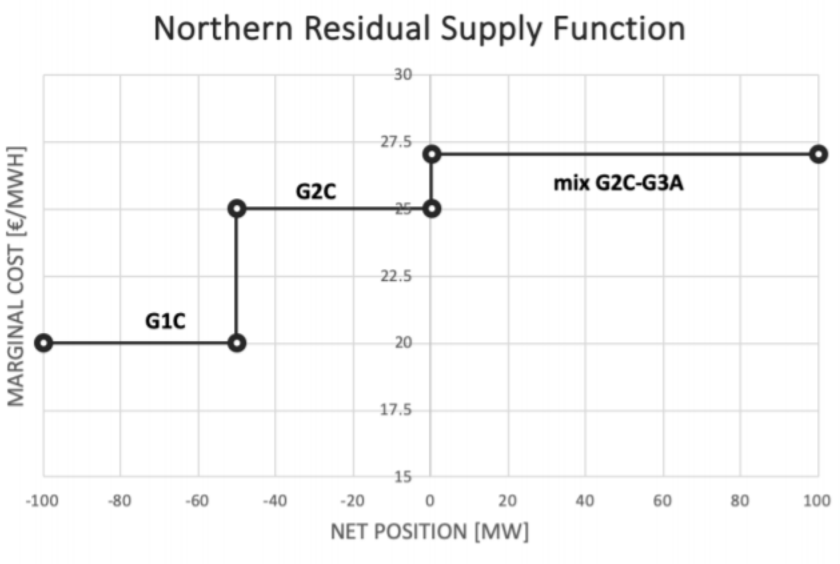


Step 2: Residual Supply Function

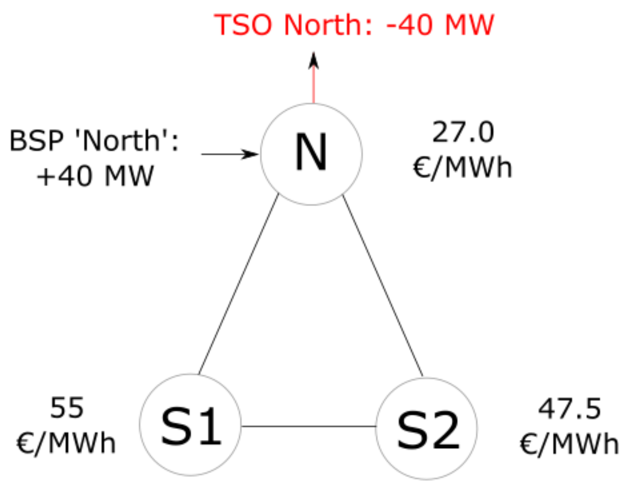
What is the least-cost way (i.e. the total cost $TC(e)$ below) in which we can export a given amount of power e from the Northern zone?

$$TC(e) = \min_{p,d,r,f} \sum_{g \in G} MC_g \cdot p_g - \sum_{l \in L} MB_l \cdot d_l$$
$$r_n = \sum_{g \in G_n} p_g - \sum_{l \in L_n} d_l, n \in N_{North}$$

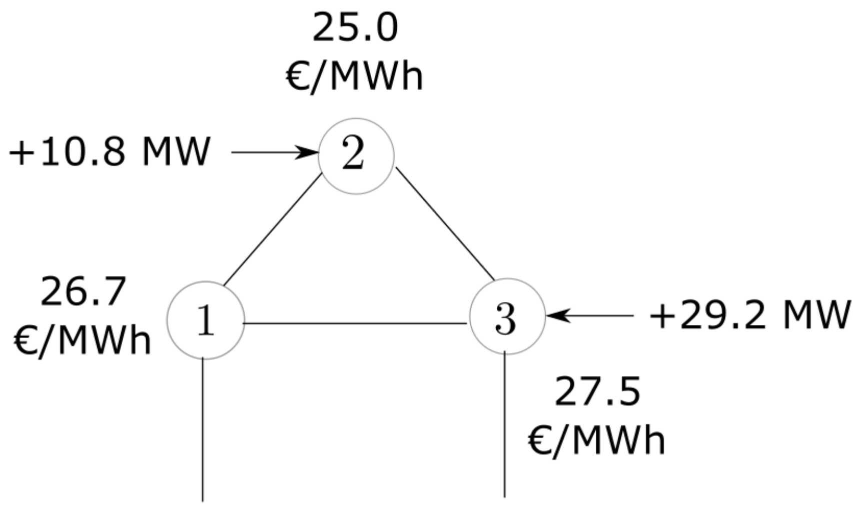
$$f_k = F_k^{South} + \sum_{n \in N} PTDF_{k,n} \cdot r_n, k \in K_{North}$$
$$-FMax_k \leq f_k \leq FMax_k, k \in K_{North}$$
$$(\pi): \sum_{n \in N_{North}} r_n = E^0 + e$$
$$p_g \leq PMax_g$$
$$p_g = P_g^0, g \in G^{Slow}, d_l = D_l^0, l \in L^{Slow}$$



Steps 3 and 4: Clear MARI and Disaggregate



Step 3: clear MARI



Step 4: disaggregate

Step 5: Settlements

	Day-ahead	Step 3 (MARI)	Step 4 (post-MARI)	Total	Total MARI + post-MARI
G1 (BSP)	7500	0	0	7500	0
G2 (BSP)	6250	0	270	6520	270
G3 (BSP)	0	0	803	803	803
BSP "North"	0	1080	0	1080	1080
L3 (BRP)	-7500	-1080	0	-8580	-1080
South BSP	17281	0	0	17281	0
South BRP	-30750	0	0	-30750	0
North TSO	3375	0	-1073	2302	-1073
South TSO	3844	0	0	3844	0
Total	0	0	0	0	0

- Northern TSO implements a nodal system within its own zone when disaggregating resources
- Northern TSO collects a payment as an aggregate BSP (step 3, MARI)
- Northern TSO uses these funds to procure balancing power in the disaggregation phase (step 4)

Legal Implementation

Compatibility of the approach has been checked against provisions of EBGL [5]

- **Merit order**: The fact that the hierarchical balancing approach produces a merit order list for MARI is consistent with EBGL requirements on submitting merit order lists in order to ensure cost-efficient activation of bids. Relevant articles are 0(11), 21(3k).
- **Compatibility with TSO-TSO model**: The definition of a TSO-TSO model is one in which the BSPs interact with nondomestic TSOs through their domestic TSO (as opposed to directly). This seems compatible with what is being proposed in the hierarchical balancing approach. Relevant article is 2(21).
- **Forwarding BSP bids to the platform**: There are certain provisions in EBGL which suggest that the TSO is required to forward its domestic bids directly to the platform. These provisions may be at odds with the aggregation that is being proposed in the pre-MARI step of the hierarchical balancing approach. Relevant articles are 2(38), 12(b), 16(2), 21(6a), 29(9), 33(3). Limitations on this practice are foreseen, subject to regulatory approval, in article 5(4e).
- **Integrated scheduling process in central dispatching**: There are explicit provisions in the EBGL regarding the conversion of bids, by TSOs operating an integrated scheduling process within a central dispatching context. The conversion of bids from an integrated scheduling process is discussed explicitly in articles 12(3c), 12(3d), 18(8d), 27(3). TSOs that wish to apply a central dispatching model need to notify the relevant regulatory authority, as foreseen in article 14(2). One concern about this interpretation is that the spirit of these provisions is to allow the mapping of bids submitted in a unit commitment tool to bids that are submitted to an exchange. Concretely, the integrated scheduling process receives information about startup cost, min up/down times, ramp rates, technical minima, min load cost, etc., whereas the balancing platforms will require much simpler bids which internalize many of these factors.

Conclusions and Next Steps

- Approach is inspired by [6] and applicable to TSO-DSO coordination
- Extensions:
  - HVDC links
  - Multi-period setting
  - Multi-product (real-reactive-reserve, i.e. 3Rs) setting
  - Location of evacuated power
  - Single TSO managing multiple bidding zones
  - Non-convex market offers
  - Granularity of residual supply function
  - …

References

- [1] I. Aravena, Q. Lete, A. Papavasiliou, Y. Smeers, Transmission Capacity Allocation in Zonal Electricity Markets, Operations Research, forthcoming
- [2] Lion Hirth and Ingmar Schlecht. Market-based redispatch in zonal electricity markets. Technical report, 2018
- [3] William Hogan. Restructuring the electricity market: Institutions for network systems. Technical report, Harvard University, 1999
- [4] N-SIDE, “Study – System balancing solutions with detailed grid data”, available online: https://www.statnett.no/contentassets/3b981e22e5d64179bb22ea9e5b46f515/2020-study---system-balancing-solutions-with-detailed-grid-data.pdf

References (II)

- [5] European Commission. Commission regulation (EU) 2017/2195 of 23 november 2017 establishing a guideline on electricity balancing. Technical report, 2017
- [6] Anthony Papavasiliou and Ilyes Mezghani. Coordination schemes for the integration of transmission and distribution system operations. In 20th Power Systems Computation Conference, 2018