

Interconnection of Norway to European Balancing Platforms Using Hierarchical Balancing

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Supply

Electricity balancing in Europe

European Guideline on Electricity Balancing

(Commission Regulation (EU) 2017/2195)

Balancing means all actions and processes,

on all timelines, through which TSOs ensure, in a continuous way, the maintenance of system frequency within a predefined stability range.



Demand



Electricity balancing in Europe



Map is illustrative only and does not indicate which countries are included in the balancing platforms

- Today, balancing is (mainly) country based, with limited cooperation among LFC areas
- Europe will move towards integrated balancing in the coming years
- Utilize resources across borders
- Capturing the benefits of trade and facilitating renewable integration
- Two main projects: MARI (mFRR) and PICASSO (aFRR)

Context and Motivation





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There is a need for Statnett to have an automated way to avoid congestions in Real Time



Bid filtering *The current approach considered by Statnett*





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Hierarchical Balancing The Residual Supply Function – the projects

Phase 1 - 2020	Phase 2 – 2021	Phase 3 - 2022
Proof of concept on the 6- node Chao-Peck network	Tests on 44-node network , a model created to be as close as possible to the Nordic system	Detailed grid simulations, based on tests within Statnett infrastructure with real data of past days of operations
+40 MW 2 40 MW 1 3 4 5 6		Pents Oce

Goal

(1) deep dive and tackle **open design questions,** and (2) quantitative assessment on the **real Norwegian** grid, using Statnett's data

Work

 (1) achieved and tested on simplified 44-nodes grid Nordic model, and (2) tested on a the full Norwegian grid model on a few subset of days provided by Statnett

Challenges

Working on data that had to **stay at Statnett premises** did not facilitate debug & testing; which is a common blocking point when working with TSOs

Potential solutions

Data anonymization could allow to work remotely and identify potential inconsistencies

Phases 2 & 3

Detailed simulations of alternative balancing solutions



Hierarchical Balancing The Residual Supply Function – the approach

"How much does it cost to export x MW?" (for all x from min to max of what can be exported) "What is the cheapest way in which we can export a given amount of power from our zone?"





Hierarchical Balancing Estimated Benefits



Less expensive solution for all Nordic TSOs, allowing to dispatch cheaper plants, disregarded otherwise

Safer operations for Statnett, by better using the existing power flow corridors

Elegant formulation that introduces the grid topology within the submitted balancing bids



Hierarchical Balancing Main Challenges Encountered

- Computational requirements of this new filtering step
- Compatibility with the normal workflow of balancing platforms
- Price deviations and financial impact that can be generated

Nevertheless, most of these challenges are being overcome

Further research is underway with Statnett, as well as in the context of TSO-DSO coordination pilots in the FEVER EU H2020 project and the ICEBERG ERC project.







Take-home message

- RSF is an elegant approach very suitable for this specific context (Norway with high hydro generation, RT congestion, MARI)
- The very same approach can also be applied for TSO/DSO Coordination
- See our papers and reports to know more, or contact us



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EXTRA MATERIAL FOR Q&A





Optimization models

Åpen informasjon / Public information

Step 2 – compute the RSF



$$TC_{z}(e) = \min_{is \geq 0, s \geq 0, p, f, r} \sum_{g \in G_{g}: Z_{g} \in Z_{NO}} MC_{g} \bullet p_{g} + VOLL \cdot \sum_{l \in LZ_{l} \in Z_{NO}} ls_{l}$$

$$+ 2 \cdot VOLL \cdot \sum_{n \in N, Z_{n} \in Z_{NO}} (s_{n}^{+} + s_{n}^{-})$$

$$P_{g}^{-} \leq p_{g} + P_{g}^{0} \leq P_{g}^{+}, g \in G_{g}: Z_{g} \in Z_{NO}$$

$$ls_{l} \leq D_{l'} l \in L: Z_{l} \in Z_{NO}$$

$$(21)$$

$$ls_{l} \leq D_{l'} l \in L: Z_{l} \in Z_{NO}$$

$$(23)$$

$$f_{k} = F_{k}^{Base} + \sum_{n \in N_{NO}} PTDF_{k,n} \bullet r_{n'} k \in K_{NO} - K_{DC}$$

$$r_{n} = \sum_{g \in G_{g'}N_{g}=n} p_{g} + \sum_{l \in L:N_{l}=n} ls_{l} + s_{n}^{+} - s_{n}^{-} -$$

$$\sum_{k \in K_{DC}:FB_{k}=n} f_{k} + \sum_{k \in K_{DC}:TB_{k}=n} f_{k'} n \in N_{NO}$$

$$\sum_{n \in N:Z_{n}=\zeta} r_{n} = 0, \zeta \in Z_{NO} - \{z\}$$

$$(n): \sum_{n \in N:Z_{n}=z} r_{n} = e$$

$$LS_{i}^{-} \leq \sum_{k \in K} A_{ki} \bullet f_{k} \leq LS_{i}^{+}, i \in LS_{NO}$$

$$(28)$$

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Åpen informasjon / Public information

Step 3 – MARI Clearing



$$\begin{split} \min_{p,f} \sum_{g \in G_{g}: Z_{g} \notin Z_{NO}} MC_{g} \bullet p_{g} + \sum_{z \in Z_{NO}} \sum_{n=1}^{N_{RSF}} 0.5 \cdot (MC_{zn} + MC_{z,n+1}) \cdot p_{zn} \\ ATC_{k}^{-} \leq f_{k} \leq ATC_{k}^{+}, k \in K \end{split}$$
(30
$$\\ \sum_{g \in G_{g}: Z_{g} = z} p_{g} = -Imb_{z} + \sum_{k \in KL:FZ_{k} = z} f_{k} - \sum_{k \in KL:TZ_{k} = z} f_{k'} z \in Z - Z_{NO} \\ \sum_{n=1}^{N_{RSF}} p_{zn} = -Imb_{z} + \sum_{k \in KL:FZ_{k} = z} f_{k} - \sum_{k \in KL:TZ_{k} = z} f_{k'} z \in Z_{NO} \\ P_{g}^{-} \leq p_{g} + P_{g}^{0} \leq P_{g'}^{+}, g \in G_{B}: Z_{g} \notin Z_{NO} \\ P_{nz}^{-} \leq p_{nz} \leq P_{nz'}^{+}, n \in \{1, ..., N_{RSF}\}, z \in Z_{NO} \end{aligned}$$
(34)

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Step 4a – quantity disaggregation

$$(Dis - Q): \min_{p,f,r} \sum_{g \in G_{g}:Z_{g} \in Z_{NO}} MC_{g} \bullet p_{g}$$

$$P_{g}^{-} \leq p_{g} + P_{g}^{0} \leq P_{g}^{+}, g \in G_{B}: Z_{g} \in Z_{NO}$$

$$(40)$$

$$p_{g} = P_{g}^{M}, g \in G_{B}: Z_{g} \in Z - Z_{NO}$$

$$(41)$$

$$\sum_{g \in G_{g}:Z_{g} = z} p_{g} = E_{z'} z \in Z_{NO}$$

$$(42)$$

$$r_{n} = \sum_{g \in G_{g}:N_{g} = n} p_{g} + Imb_{n}, n \in N$$

$$(43)$$

$$T_{k} = F_{k}^{Base} + \sum_{n \in N} PTDF_{k,n} \bullet r_{n'} k \in K_{NO} - K_{DC}$$

$$-FMax_{k} \leq f_{k} \leq FMax_{k'} k \in K_{NO}$$

$$(45)$$

$$LS_{i}^{-} \leq \sum_{k \in K} A_{ki} \bullet f_{k} \leq LS_{i}^{+}, i \in LS_{NO}$$

$$(46)$$

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Simulation results

(preliminary)



Latest simulations

Semi-industrial setup within Statnett system

- Running on 3 days of previous real data
- 4 sets of KPIs investigated, with appealing results
 - I. What is the financial impact for Statnett?
 - II. How restrictive is the RSF method compared to non-filtered aggregated offers?
 - III. How risky for the network is this method?
 - IV. What is the cost of activation for Norwegian producers?

New report incoming, stay tuned to know more!



or

