# Integrating RES-E in Balancing Markets by harmonising procurement of FRR in selected Central European Countries

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4th September 2017
15th European IAEE Conference

# Overview

- Motivation
- Research Question & Analysed Scenarios
- “EDisOn+Balancing“ Model
- Results for the year 2015
  - Impacts on the cost structure
  - Interdependencies on procured capacities and exchanges
  - Environmental impacts
- Conclusions

# Motivation

**European Goal:** successful achievement and implementation of the Internal Energy Market – IEM

- ENTSO-E → Network Code on Electricity Balancing (NC EB) has been approved on $16^{th}$ March 2017
- several pilot projects concerning Balancing have already started, e.g.
  - harmonising the product design of aFRR in Germany and Austria,
  - common activation of aFRR by the German an Austrian TSOs (started in July 2016),
- further plans are…
  - to harmonise the product design of mFRR and RR,
  - to implement common procurement of aFRR in Austria and Germany (2017),
  - to achieve common activation and procurement of mFRR in Austria and Germany,
  - to enlarge the region of common balancing.

FRR = Frequency Restoration Reserve (manually and automatically activated)

# Research Question & Analysed Scenarios

## Questions

- What savings can be achieved by harmonising and shortening balancing procurement?
- What implications can be expected if common procurement for aFRR is applied?
- What interdependencies on aFRR and the wholesale market can be observed, if also mFRR is procured commonly?

## Scenarios

Ref. Current Design
(weekly P and OP products, thermal plants and PHS can procure FRR)

A. 4h-products for aFRR
B. A & common procurement aFRR
C. B & common procurement mFR

FRR = Frequency Restoration Reserve (manually and automatically activated)
P = Peak, OP = Off-Peak, WE = Weekend, HT = Peak, NT = Off-Peak, 4h = 4-hour-products

# “EDisOn+Balancing” Model

= **E**lectricity **Dis**patch **O**ptimizatio**n: Linear Programming (LP)** developed in MATLAB®

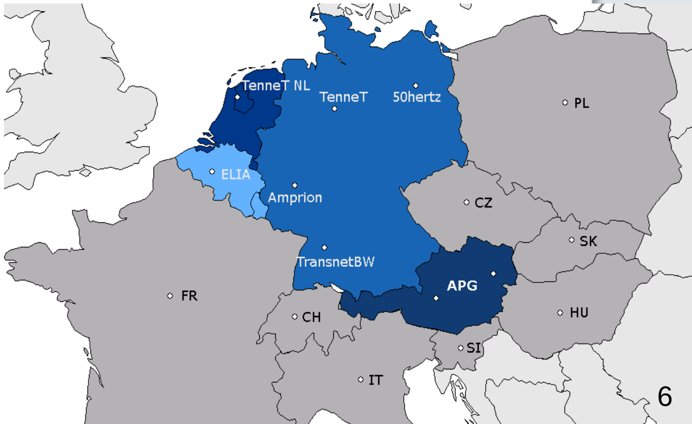
- objective function:

  minimising (wholesale generation costs) + (procurement costs of a&m FRR)

- constraints:
  - electricity generation: demand = supply
  - heat: demand = supply (power-to-heat and CHPs)
  - balancing procurement: required = supply
  - capacity restrictions of power plants
  - ramping limits and start costs of thermal power plants
  - reservoir level equations for hydro storages and other storages
  - spillage of RES-E (solar, wind, natural inflow) and Not Supplied Energy (NSE)
  - power flows, injections and exchanges via Net Transfer Capacity (NTC) or DC power flow approach

# “EDisOn+Balancing” Model

- functionalities:
  - deterministic and assumes a perfectly competitive market with perfect foresight
  - hourly resolution of a whole year at country level for Central Europe
  - rolling horizon optimization (weekly or daily)
  - wholesale market and balancing market split into control areas
  - control areas can be split into balancing groups
  - different product designs for aFRR are possible (P, OP, WE, HT, NT → 4h) & mFRR
  - thermal power plants and pumped hydro storages can procure balancing capacity (incl. ramping)
  - implicite allocation of transmission capacity for balancing
- geographical scope:
  - wholesale: AT,DE,NL,BE,FR,CH,IT,SI,HU,SK,CZ & PL.
  - balancing: APG, TransnetBW, Amprion, TenneT, 50Hertz, TenneT NL & ELIA.

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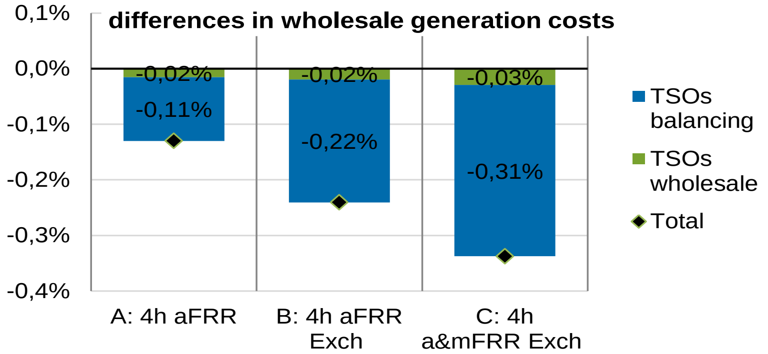
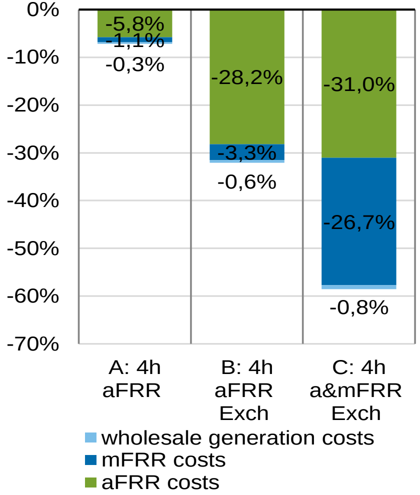
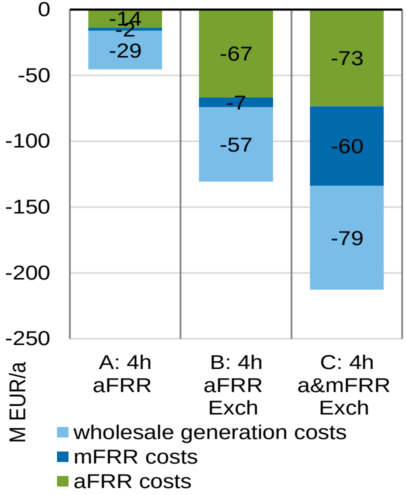
# Results: Impacts on the cost structure

- wholesale generation costs are …
  - mostly influenced by the TSOs, where balancing is respected;
  - reduced by 0.34 % in Case C, which are 90 MEuro/a for the whole region.




- total costs for TSOs balancing
  - introduction of common procurement has got higher impacts than changing product design only (compare B&C with A)
  - common procurement of mFRR has positive effects on the costs of aFRR



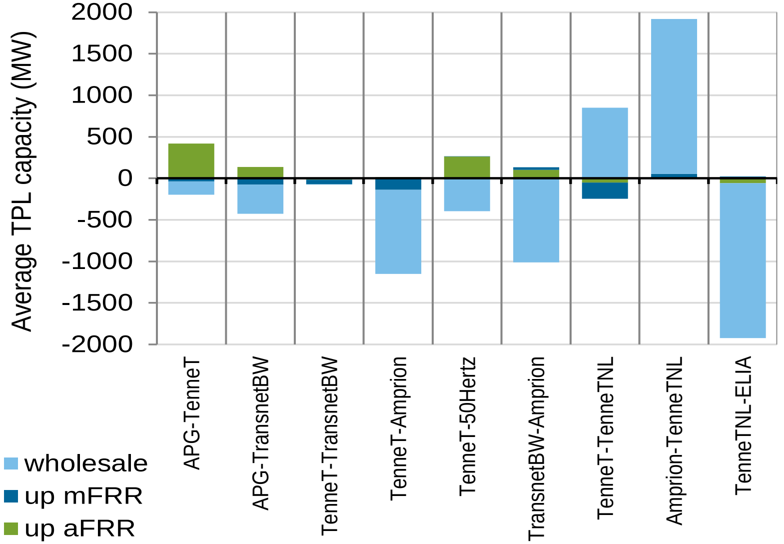

TSOs balancing are NL, BE, DE & AT.

# Results: Interdependencies on procured capacities and exchanges (I)

- Average hourly flows of wholesale electricity market clearing and the reserved capacity for upward FRR (case C) on transmission lines:
  - mostly used for wholesale electricity market flows
  - on interconnections
    - APG-TenneT, APG-TransnetBW, TenneT-50Hertz, TransnetBW-Amprion,

    it is often used for providing upward aFRR
  - on interconnections
    - TenneT-TransnetBW, TenneT-Amprion, TenneT-TenneTNL

    capacity is used for upward mFRR

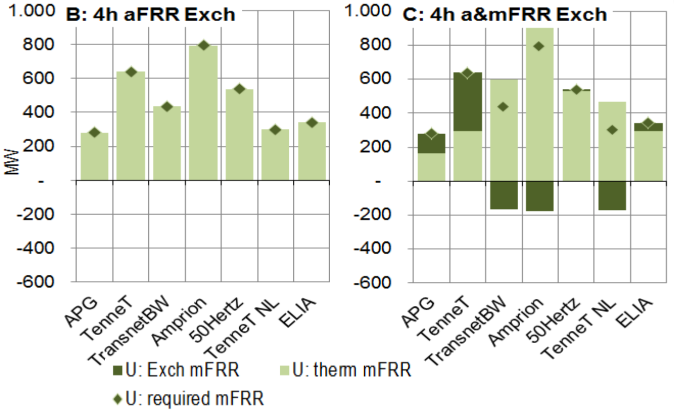



For the transmission line APG-TenneT positive values mean, that APG provides upward FRR or exports energy to TenneT, negative vice versa.

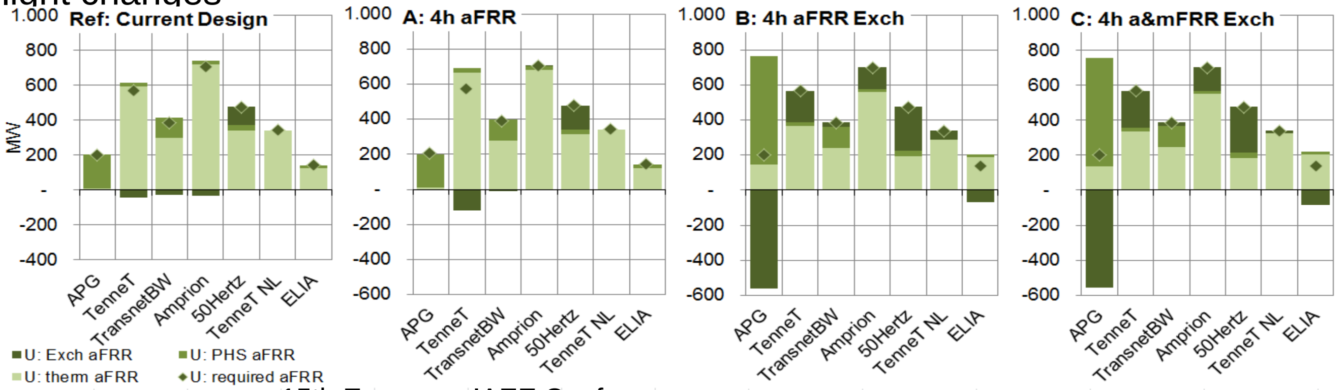
# Results: Interdependencies on procured capacities and exchanges (II)

- average procured capacity for upward mFRR
  - B→C: TransnetBW, Amprion and TenneT NL provide balancing capacity to APG and TenneT
- and aFRR:
  - Ref→A: TenneT provides aFRR to the remaining German TSOs
  - A→B: Austrian PHS procure a significant amount of aFRR for German TSOs
  - B→C: only slight changes

**mFRR**




**aFRR**



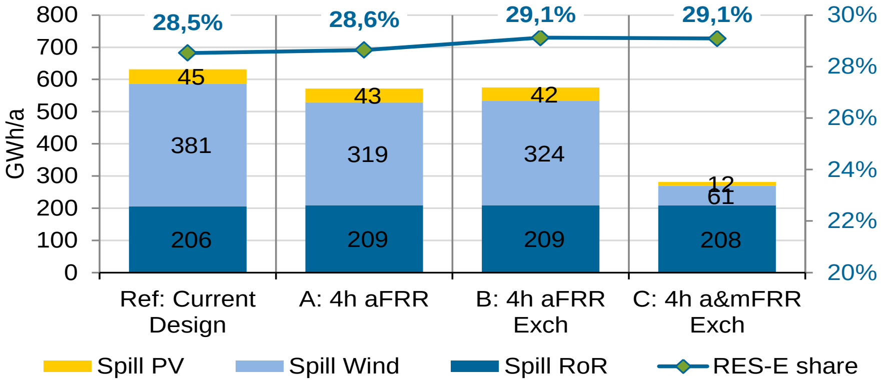
# Results: Environmental impacts

- $CO_2$ emissions:
  - the total amount is reduced in all cases
  - A: emissions for balancing increase, due to more flexibility in product design

| | total | wholesale | | balancing | |
|---|---|---|---|---|---|
| $CO_2$ Emissions ($MtCO_2/a$) | All | AT | All | AT | All |
| Ref: Current Design | **610.3** | 9.3 | 567.5 | 2.0 | 42.9 |
| A: 4h aFRR | **-0.2%** | -0.5% | -0.3% | 4.9% | 1.2% |
| B: 4h aFRR Exch | **-1.4%** | -0.8% | -1.5% | 28.0% | -0.7% |
| C: 4h a&mFRR Exch | **-1.8%** | -1.8% | -1.4% | -7.5% | -7.0% |

- RES-E spillage & RES-E share:
  - spillage decreases in all cases
  - mostly wind spillages can be avoided
  - RES-E share increases

$$\text{RES} - \text{E share} = \frac{\text{PV} + \text{Wind} + \text{Biomass} + \text{RoR} + \text{PHS} - \text{Pump} \cdot \eta}{\text{Demand}}$$



# Conclusions

- Implementation of shorter balancing products and allowing common procurement of aFRR and mFRR by all TSOs reduces costs for procurement significantly.
- $CO_2$ emissions can be reduced by around 1.7% in Austria and by 1.4% for the respected area in total.
- The spillage of renewable generation can be bisected in Austria and the whole region.
- The renewable share of electricity generation is increased to 29.1% (+0.6%) in the respected area.

| KPIs for Total System | Ref: Current Design | A: 4h aFRR | B: 4h aFRR Exch | C: 4h a&mFRR Exch |
|---|---|---|---|---|
| wholesale generation costs (Meuro/a) | 25617 | -0,1% | -0,2% | -0,3% |
| FRR procurement costs (Meuro/a) | 463 | -3,5% | -16,0% | -28,9% |
| total costs (Meuro/a) | 26080 | -0,2% | -0,5% | -0,8% |
| wholesale $CO_2$ emissions ($MtCO_2$/a) | 567 | -0,3% | -1,5% | -1,4% |
| FRR $CO_2$ emissions ($MtCO_2$/a) | 43 | 1,2% | -0,7% | -7,0% |
| total $CO_2$ emissions ($MtCO_2$/a) | 610 | -0,2% | -1,4% | -1,8% |
| RES-E spillage (GWh/a) | 632 | -9,6% | -9,0% | -55,4% |
| RES-E share (%) | 28,5% | 0,4% | 2,1% | 2,0% |

# Comparing 2015 with 2030



## 2015

| KPIs for Total System | Ref: Current Design | A: 4h aFRR | B: 4h aFRR Exch | C: 4h a&mFRR Exch |
|---|---|---|---|---|
| wholesale generation costs (Meuro/a) | 25617 | -0,1% | -0,2% | -0,3% |
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## 2030

| KPIs for Total System | Ref: P/OP weekly | A: P/OP daily | B: P/OP w sym | C: P/OP d sym | D: 4h aFRR | E: 4h aFRR Exch | F: 4h a&mFRR Exch | G: 4h a&mFRR Exch wOthStor |
|---|---|---|---|---|---|---|---|---|
| wholesale generation costs (Meuro/a) | 33492 | -0,2% | 1,4% | 1,1% | -0,2% | -0,3% | -0,4% | -0,4% |
| FRR procurement costs (Meuro/a) | 850 | -6,5% | 34,5% | 27,7% | -10,7% | -7,7% | -9,7% | -9,9% |
| total costs (Meuro/a) | 34342 | -0,3% | 2,2% | 1,8% | -0,5% | -0,5% | -0,6% | -0,6% |
| wholesale $CO_2$ emissions ($MtCO_2$/a) | 323 | 0,1% | 0,8% | 0,6% | 0,0% | -0,2% | -0,2% | -0,2% |
| FRR $CO_2$ emissions ($MtCO_2$/a) | 29 | -3,4% | 12,5% | 14,6% | -1,5% | -7,6% | -4,5% | -9,5% |
| total $CO_2$ emissions ($MtCO_2$/a) | 353 | -0,2% | 1,7% | 1,8% | -0,1% | -0,8% | -0,5% | -0,9% |
| RES-E spillage (GWh/a) | 15252 | -1,7% | 11,6% | 7,7% | -2,4% | -2,2% | -2,8% | -2,8% |
| RES-E share (%) | 58,3% | 0,0% | -0,5% | -0,4% | 0,1% | 0,2% | 0,2% | 0,2% |

# Future work

- analysing the impacts of considering wind farms as balancing capacity provider (especially for mFRR),
- including demand side management,
- simulating the activation of balancing energy,
- include stochasticity in renewable generation,
- etc.

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# Assumptions: European grid