Optimizing Congestion Management by Integrating Redispatch into the Day-ahead Market

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PREMISE

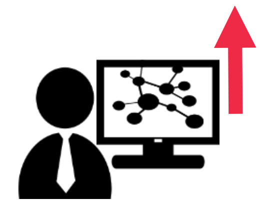
Current challenges:

- Highly meshed European network
- Growing shares of variables renewables
- Growing costs of redispatch
- **Intrazonal congestion can limit cross-border exchange, leading to zonal splitting and decreasing economic welfare**

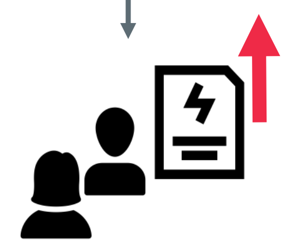
Current approach to redispatch is suboptimal:

- Does not attempt to find an optimal solution to a congestion
- Only a few large generators usually redispatched
- TSO (and consumers) incur additional costs for post-market measures

A copper plate assumption does not adequately represent the actual grid.



Redispatch costs: e.g. ~€1bn in 2018 by German TSOs alone



Growing electricity prices & grid tariffs for consumers

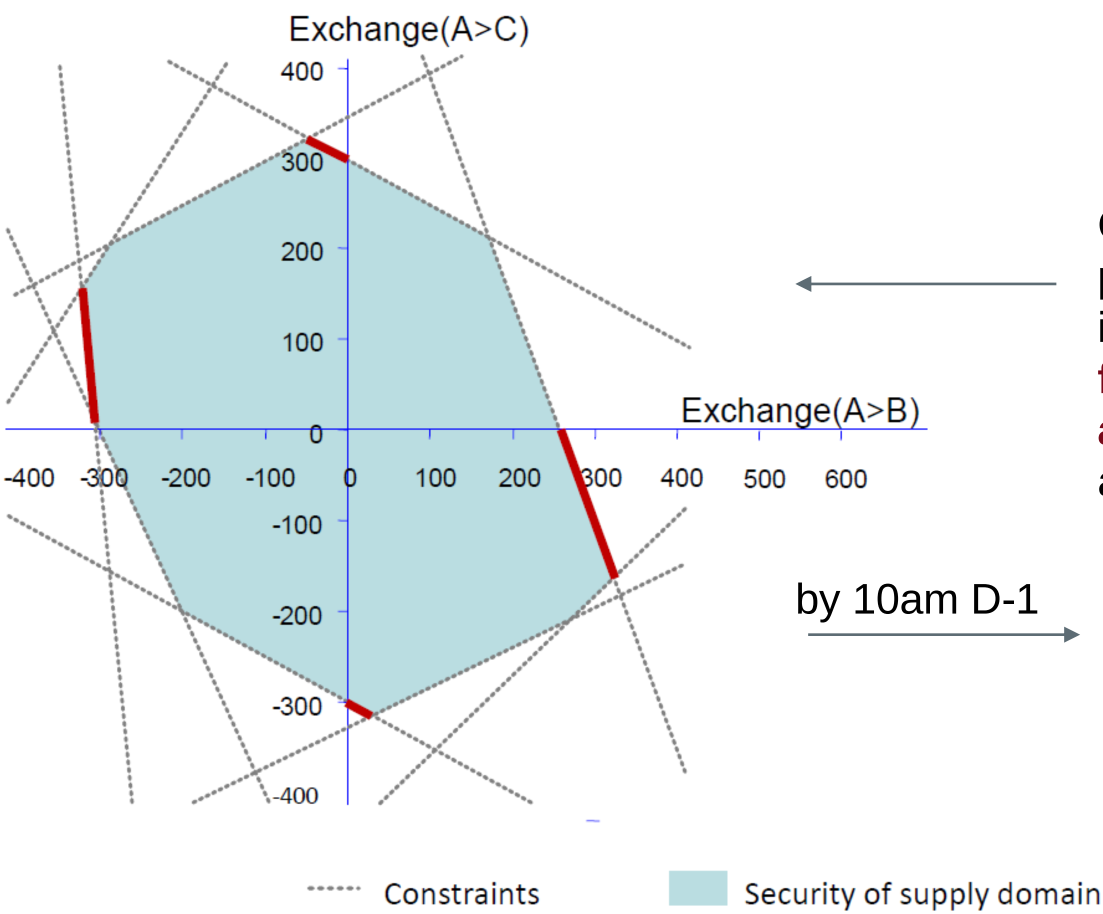
SOLUTION?

Optimize the use of redispatch by integrating it into the DA market and potentially:

- **reduce redispatch costs,**
- **improve the availability of interconnector capacity for cross-border exchange by allowing IRD generators to free up the needed capacity on congested lines and increase cross-border trade.**
- **Increase overall economic surplus.**

NODAL MARKET	ZONAL with integrated redispatch (IRD)	ZONAL MARKET with flow-based market coupling
All grid constraints are considered	Grid constraints are considered for generators used for integrated redispatch, which is “co-optimized” with the DA market.	Most intrazonal grid constraints are disregarded; *ex post* redispatch needed in the event of a congestion

FLOW-BASED MARKET COUPLING (FBMC)



Choice of **critical branches (CBs)**, interconnectors **and** internal branches

D-2

Congestion forecast: FB parameters determined *ex ante*, i.e. **zonal power distribution factors (PTDFs)** and **remaining available margins (RAM)** per CB and zone.

by 10am D-1

Cross-border capacity allocation for short-term trade

DA market GCT 12pm D-1

Source: Amprion, apx, Belpex, Creos, elia, EPEX SPOT, Rte, TenneT, Transnet BW (2013)

MODEL OVERVIEW

- Linear multi-step optimization models for three market types, nodal market, zonal market with FBMC and the novel zonal approach with integrated redispatch respecting FBMC principles as implemented in the CWE
- Models tested an verified on two- and three-zone networks
- Outputs: flow-based parameters and the distribution of costs and rents for all the stakeholders (consumers, suppliers, TSO).

NODAL SETUP

Nodal market

OUTPUT

1. Optimal dispatch respecting all grid constraints
2. Nodal prices
3. In case of a congestion: per-branch congestion rent for the TSO

Objective function:

$$\min \sum_{g}^{G} \boldsymbol{d}_g * c_g$$

where
$\boldsymbol{d}g$ – dispatch of generator
cg – marginal cost of generator
$\boldsymbol{f}b$ – flow on a branch
$\boldsymbol{p}n$ – nodal power injection
FRM- flow reliability margins

subject to nodal energy balance,
capacity limits of generators,
and flow limits:

$$-(F_b - FRM_b^{nod}) \leq \boldsymbol{f}_b \leq (F_b - FRM_b^{nod}) \;, \qquad \forall b$$

$$\boldsymbol{f}_b = \sum_{n} PTDF_{b,n}^{nod} * \boldsymbol{p}_n$$

ZONAL SETUP WITH FBMC

- $\boldsymbol{d}_g$ – dispatch of generator
- c_g – marginal cost of generator
- $\boldsymbol{f}_b$– flow on a branch
- $\boldsymbol{d}_z$ – total zonal dispatch
- $\boldsymbol{rdPF}$ – RD price factor

Base Case

the expected outcome of the
delivery as forecasted two d
Adjusted formulation from th

reference values

FBMC

Objective function

$$\min \sum_{g}^{G} \boldsymbol{d}_g * c_g$$

subject to zonal energy balance, capacity constraints, zonal flows using zonal PTDFs and GSKs:

$$\boldsymbol{f}_b^{FBMC} = f_b^{ref} + \sum_{z}^{Z} PTDF_{b,z}^{zon} * \Delta\boldsymbol{d}_z , \qquad \forall\, b \ in\ CB$$

$$PTDF_{b,z}^{zon} = \sum_{n}^{N_Z} PTDF_{b,n}^{nod} * GSK_{n,z} , \qquad \forall b \in CB, \forall z \in Z$$

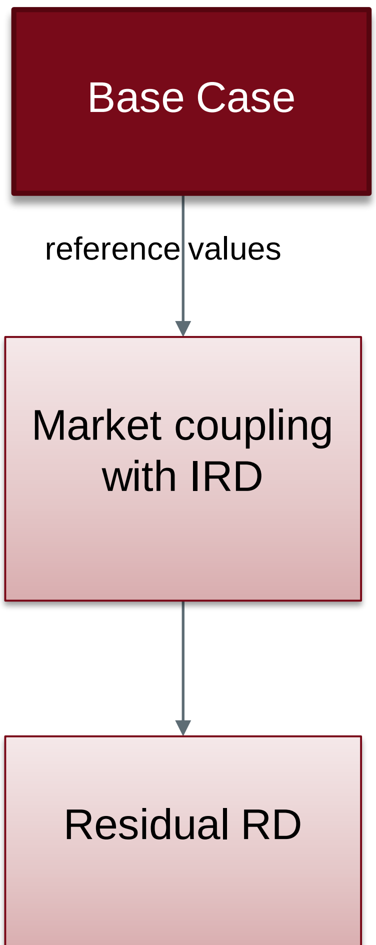
ERD

Objective function:

$$\min \sum_{g}^{G^{RD}} \gamma \left(c_g^{DA} * rdPF * \Delta\boldsymbol{d}_g^{pos} - \frac{c_g^{DA}}{rdPF} * \Delta\boldsymbol{d}_g^{neg} \right) + \lambda * price_{z(g)}^{FBMC} * (\Delta\boldsymbol{d}_g^{pos} + \Delta\boldsymbol{d}_g^{neg})$$

which either minimizes the volume of redispatch (lambda = 1) or its cost (gamma =1)

ZONAL IRD SETUP



MAIN FEATURES

- A set of dispatchable generators is used for integrated redispatch (IRD) in the event of a congestion
- IRD action is "co-optimized" with the DA market
- IRD units participate in the DA market
- Nodal PTDFs are used for IRD generators and included in the flow calculation
- Zonal PTDFs and GSKs are used for the rest of the generators
- The dispatch of more expensive IRD units does **not** affect DA market price
- Some residual redispatch might still be needed to fully alleviate a congestion

ZONAL IRD SETUP

Base Case

the expected outcome of the DA market for the time of delivery as forecasted two days ahead (D2CF)
Adjusted formulation from the nodal setup was used.

reference values

Market coupling with IRD

Objective function either:

1) Minimizes total system costs
   (incl. IRD based on its volume or costs) or
2) Maximizes export ("at all costs")

subject to zonal energy balance, capacity constraints, <u>nodal PTDFs for IRD units</u> and zonal PTDFs for the rest

→ The first objective function (with cost minimization) was chosen. Results presented in the next slides

Residual RD

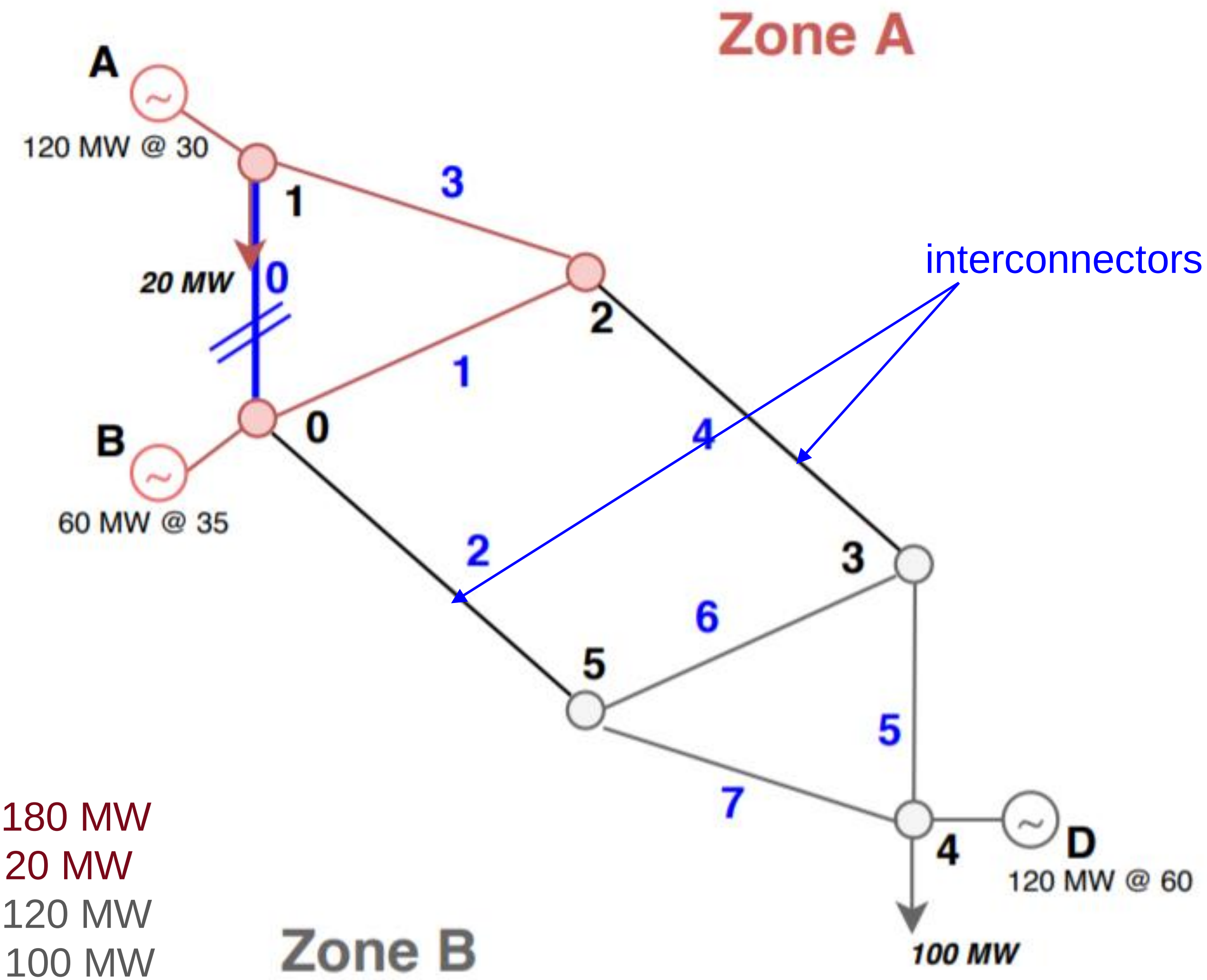
Same formulation as for the ex-post redispatch in Business-as-usual setup:

$$\min \sum_{g}^{G^{RD}} \gamma \left(c_g^{DA} * rdPF * \Delta \boldsymbol{d}_g^{pos} - \frac{c_g^{DA}}{rdPF} * \Delta \boldsymbol{d}_g^{neg} \right) + \lambda * price_{z(g)}^{FBMC} * (\Delta \boldsymbol{d}_g^{pos} + \Delta \boldsymbol{d}_g^{neg})$$

EXAMPLE: 6-NODE NETWORK

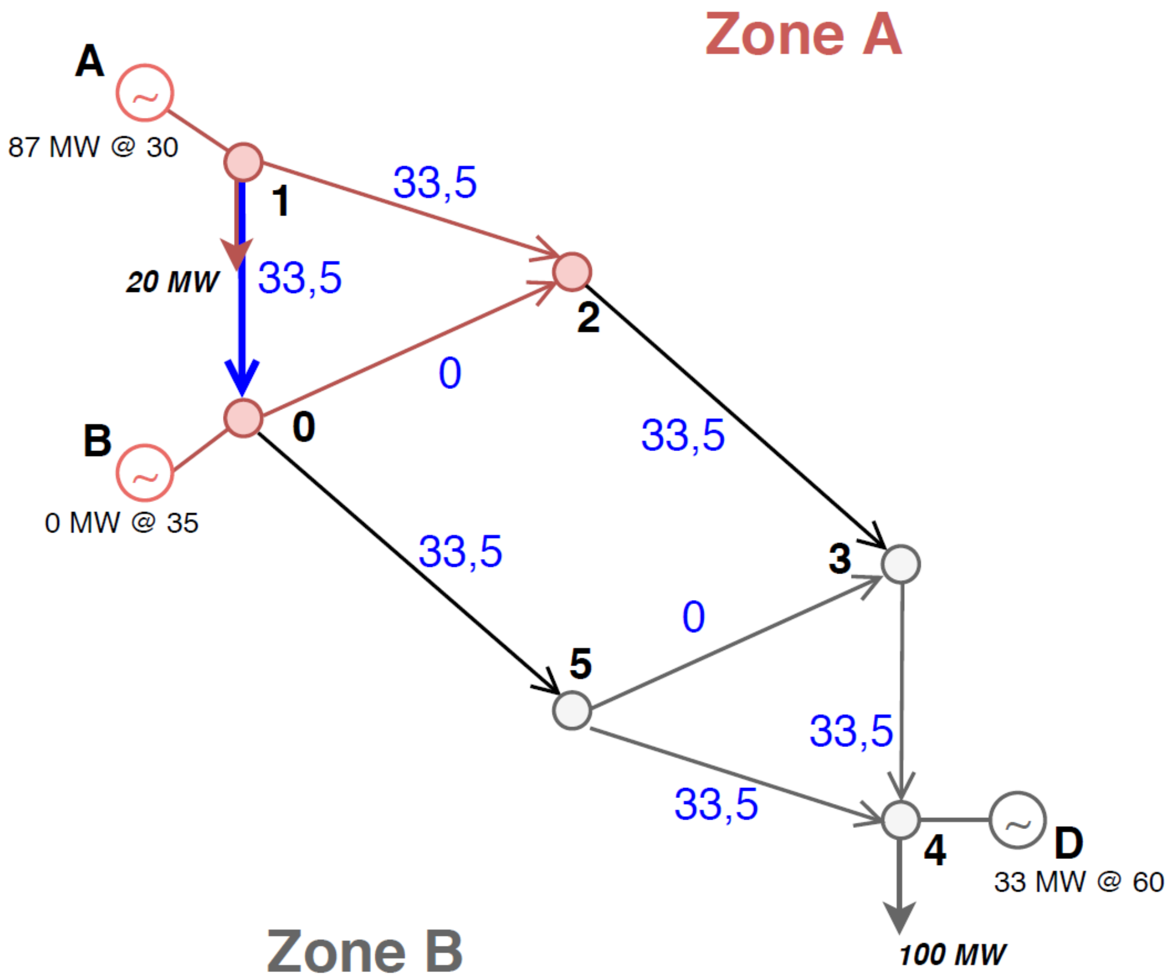
Line limits: 120 MW on each branch, except for branch 0: 30 MW

Equal line reactances



Installed capacity **Zone A:** 180 MW
Total load **Zone A:** 20 MW
Install capacity **Zone B:** 120 MW
Total load **Zone B:** 100 MW

RESULTS –
BUSINESS-AS-USUAL, FBMC

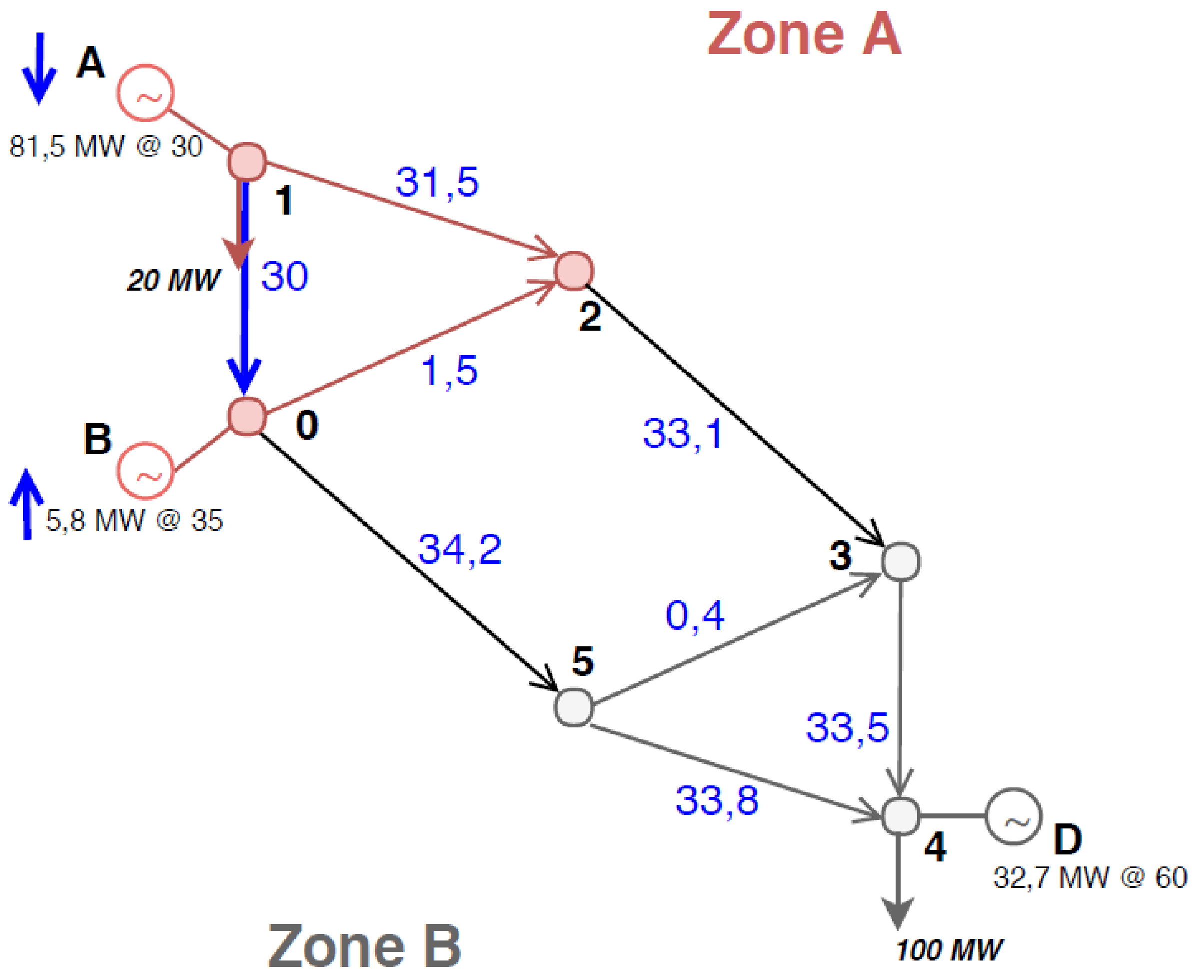


Result of DA market merit-order dispatch is **infeasible**

Total cross-zonal flow: 67,3 MW

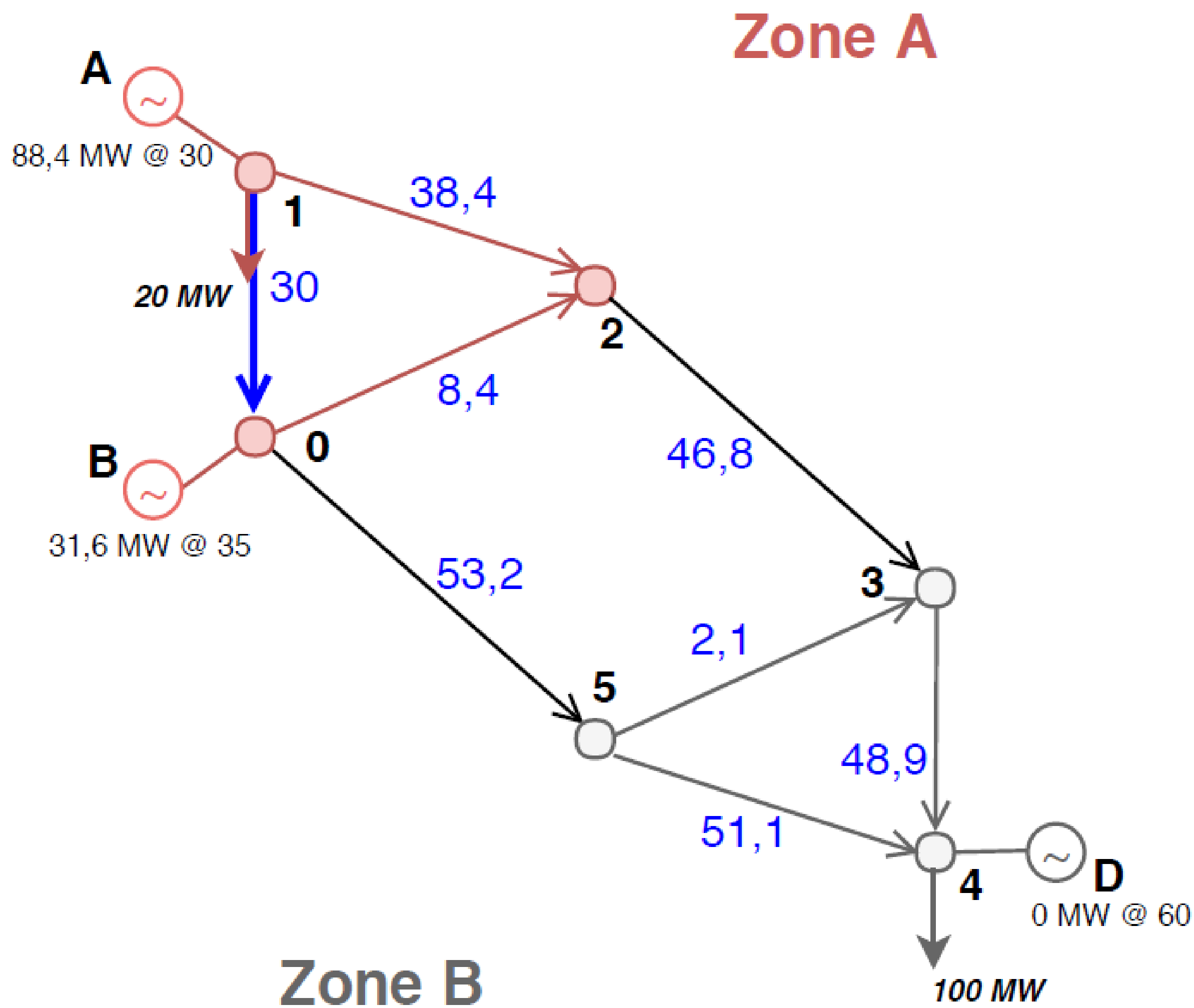
RESULTS – BUSINESS-AS-USUAL, EX-POST REDISPATCH

Redispatch in Zone A
5,8 MW
in each direction



Total cross-zonal flow:
67,3 MW

RESULTS –
ZONAL WITH INTEGRATED REDISPATCH, IRD



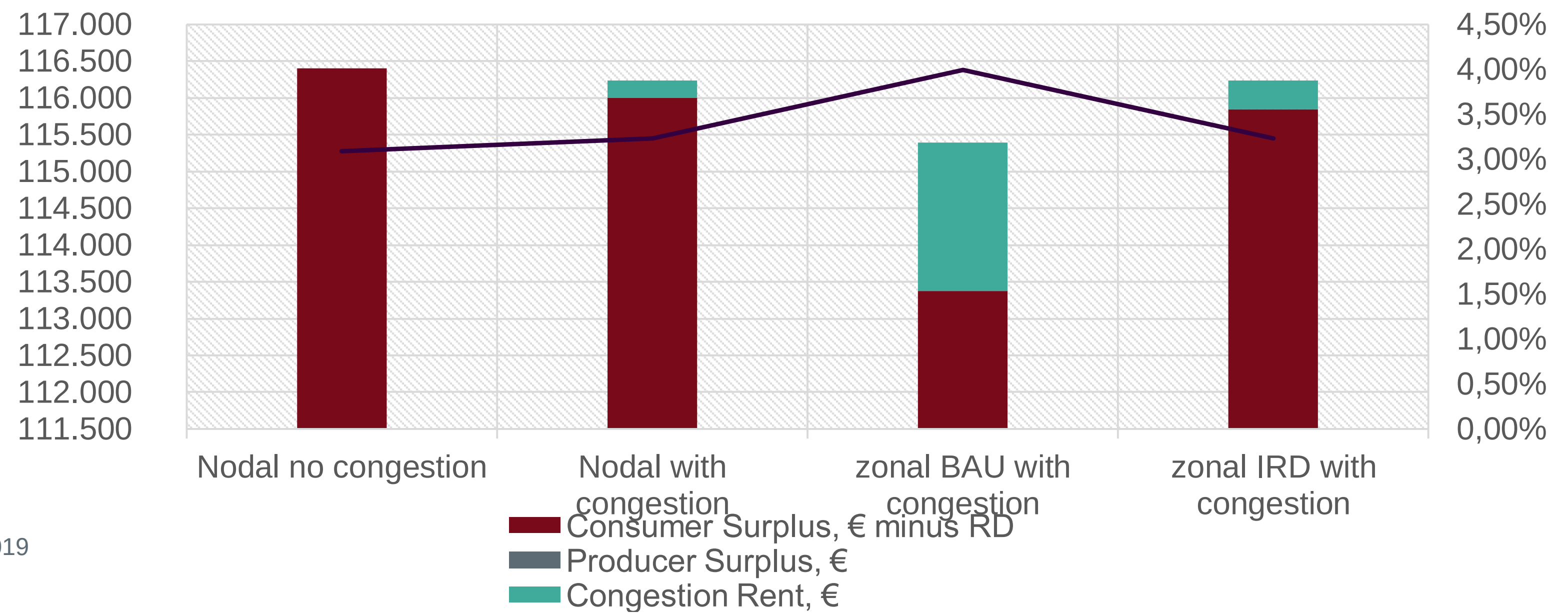
Total cross-zonal flow: 100 MW

NO residual redispatch necessary

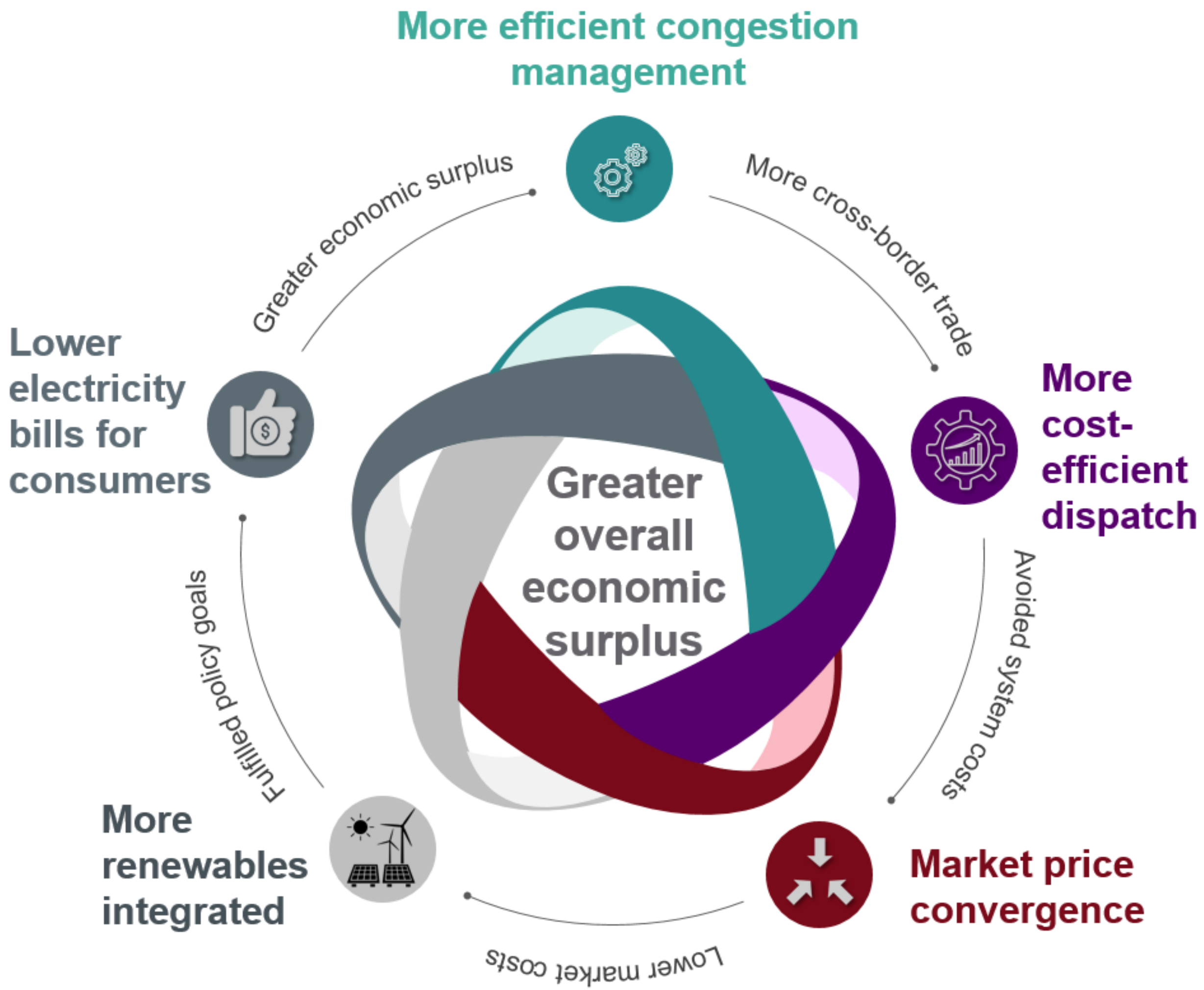
MULTIPLE TEST SCENARIOS CONFIRMED:

- IRD approach helps increase the available transmission capacity between zones (in the example: 67MW vs. 100MW) by preventing a congestion and zonal price convergence thanks to a more efficient dispatch.
- Consideration of IRD generator in FBMC process helps to increase price convergence (in the example: 30€/MWh in Zone A & 60€/MWh in Zone B vs. 30€/MWh in Zone A & 34€/MWh in Zone B in zonal with IRD).
- Optimized congestion management helps reduce the burden on the consumers.
- In most scenarios, *ex post* measures unnecessary, reducing system and transaction costs.

→ Compared to a fully nodal market, IRD approach can be a good realistic alternative to the current approach.



BENEFITS


More efficient congestion management
More cross-border trade
More cost-efficient dispatch
Avoided system costs
Market price convergence
Lower market costs
More renewables integrated
Fulfilled policy goals
Lower electricity bills for consumers
Greater economic surplus
Greater overall economic surplus

THANK YOU!

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