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A review of practical aspects of existing TSO-DSO coordination mechanisms in Europe and proposal of an innovative hybrid model in ATTEST project

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Introduction

- Ambitious goals set by the European Union in the transition towards carbon-neutral environment
- Broad integration of RES requires different approach in distribution network management
- ‘Fit and forget’ replaced with Active Distribution Network Management
- Participation of DERs in AS provision
- Coordination between system operators is required to prevent the activation of counteracted services

TSO/DSO coordination mechanisms

- To ensure efficient system operation, optimal utilization of resources and minimal cost for all system operators
- The role of the DSO should be extended
- 5 categories:
  - Centralized AS market model
  - Local AS market model
  - Shared balancing responsibility model
  - Common TSO-DSO AS market model
  - Integrated flexibility market model

Flexibility service	Congestion management	Frequency control	Voltage control
Centralized AS market model	+	+	-
Local AS market model	+	-	+
Shared balancing responsibility model	+	-	+
Common TSO-DSO AS market model	+	+	+
Integrated flexibility market model	+	-	-

Centralized AS market model

- The TSO is the only buyer of AS
- The DSO is responsible for the product prequalification, but cannot procure flexibility services

+	-
similar to the existing approach (easy to implement when it comes to regulatory questions)	increased computational complexity if system prequalification is organized to meet the distribution network constraints
only one market with high liquidity and simple operation with clearly defined market products	if the TSO is not involved in the system prequalification, distribution network constraints can be violated

Local AS market model

- The DSO has the priority in procuring AS from DERs and remaining flexibility can be offered to the TSO

+	-
extended role of the DSO – in charge of local market clearing	not in line with the current market regulation
distribution network constraints considered in market clearing	additional investment in communication technology to ensure RT data exchange
market fragmentation – development of tailor-made products satisfying the needs of the specific market	several local markets with low capability of aggregation resulting in low market liquidity

Shared balancing responsibility model

- Roles of system operator are completely separated

+	-
extended role of the DSO – balancing in the distribution network	increased number of local flexibility resources is required
low computational complexity due to separate optimization processes and limited data exchange	local markets with low liquidity and limited sources of flexibility – high price of AS, load shedding or RES curtailment
the TSO will face lower cost due to reduced balancing responsibility	a threat to global stability if the DSO fails in local balancing

Common TSO-DSO AS market model

- One common AS market jointly operated by the TSO and DSO

+	-
the most efficient allocation of resources	the most complex coordination
one market clearing considering transmission and distribution network constraints	cost division between system operators is complex due to join market operation and service procurement
Market operated jointly by both system operators – the most economical solution	investment in additional communication infrastructure

Integrated flexibility market model

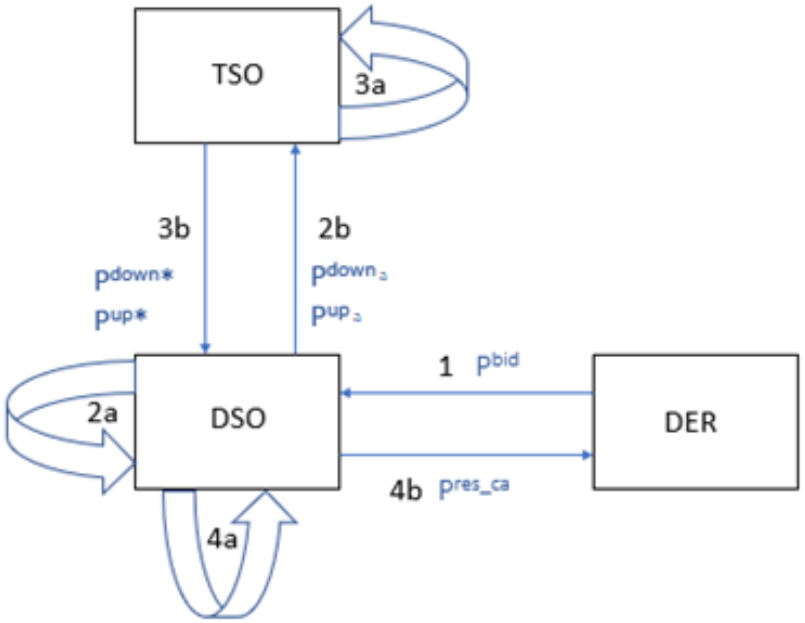
- Regulated and deregulated market participants have access to the central market→ direct competition between market players
- System operators can resell AS which they do not need

+	-
high liquidity due to high number of participants and competitive bids	high computational effort
transmission and distribution network constraints considered in the market clearing	increased competition might lead to AS procurement outside the market

ATTEST TSO/DSO coordination approach

- A two-stage AS procurement divided in day-ahead (DA) and real-time (RT) operation
- Services related to active and reactive power bids are part of one tool executed in two steps
- Results of DA energy market clearing considered in the AS coordination between system operators
- Due to complexity of pricing mechanism for the coupled P-Q bid for AS, bids for active and reactive power are decoupled and independently submitted to the DSO with the constant cost per offered unit of energy

Reservation of active power services at DA operation planning stage



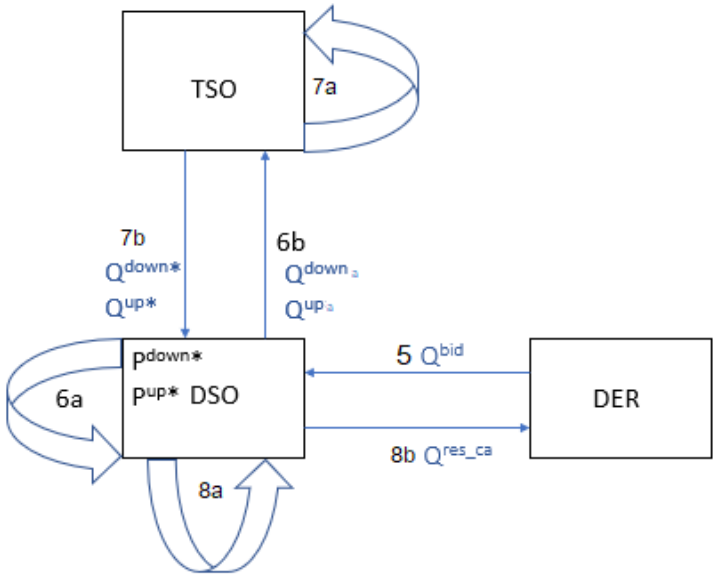
1) DERs submit their active power bids to the DSO divided in up and down bids with the corresponding cost.

2a) The DSO runs the AC OPF ensuring the DSO network constraints are met.
2b) The DSO submits active power flow range to global P market.

3a) The TSO runs the AC Security Constrained OPF to define the range of required flexibility.
3b) The TSO sends to the DSO cleared bids for up and down reserved capacity of AS defined as the range $[P^{DA} - P^{down*}, P^{DA} + P^{up*}]$ at the TSO-DSO interface.

4a) DSO clears the local market in order to optimize distribution network operation with the respect of agreed Pup^* and $Pdown^*$.
4b) DSO sends the request for active power capacity reservation to DERs.

Reservation of reactive power services at DA operation planning stage



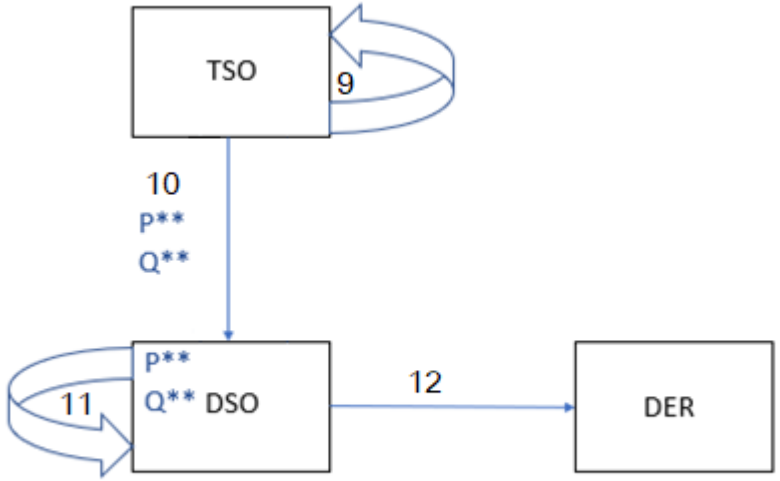
5) DERs submit their reactive bids to the DSO divided in up and down bids.

6a) The DSO runs AC OPF and determines Q flow range at TSO-DSO interface with fixed $[P^{DA}-P^{down*}, P^{DA}+P^{up*}]$.
6b) The DSO submits Q flow range bids capability to global Q market run by TSO.

7a) The TSO determines the required flexibility to satisfy voltage constraints.
7b) The TSO sends to the DSO cleared bids for up Qup^* and down $Qdown^*$. regulation as the range $[Q^{DA}-Q^{down*}, Q^{DA}+Q^{up*}]$ at the TSO-DSO interface.

8a) DSO clears the local market in order to solve local problems with the respect of agreed $Pup^*, Pdown^*, Qup^*$ and $Qdown^*$.
8b) DSO sends the request for reactive power capacity reservation.

Activation of active and reactive power services in real-time operation



9) The TSO runs the SCOPF in RT and determines the required AS P^{**} and Q^{**} . Frequency security constraints will be integrated in the SCOPF formulation in a newly developed ATTEST tool for on-line dynamic security assessment.

10) The TSO sends to the DSO the desired active power P^{**} and reactive powerQ^{**}.

11) The DSO runs RT OPF with the fixed P^{**} and Q^{**} values at the TSO/DSO interface and clears the local RT market making sure to satisfy DG constraints.

12) The DSO sends signals to activate the flexibility providers / DERs.

Conclusion

- ATTEST coordination model – a hybrid model between Centralized, Local and Shared balancing responsibility market model.
- TSO has the priority in AS reservation.
- DSO procures AS from DERs for solving local congestion management and voltage deviations.
- The role of the DSO is extended to ensure that reserved capacity of AS in DA market provided by DERs is delivered to the TSO in the RT.
- Solution sub-optimal for the DSO and does not distribute costs between system operators → should be renumerated in some extent by the TSO.
- Distribution network constraints are considered in the market clearing approach.
- Heavy calculation challenges due to precise communication.

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